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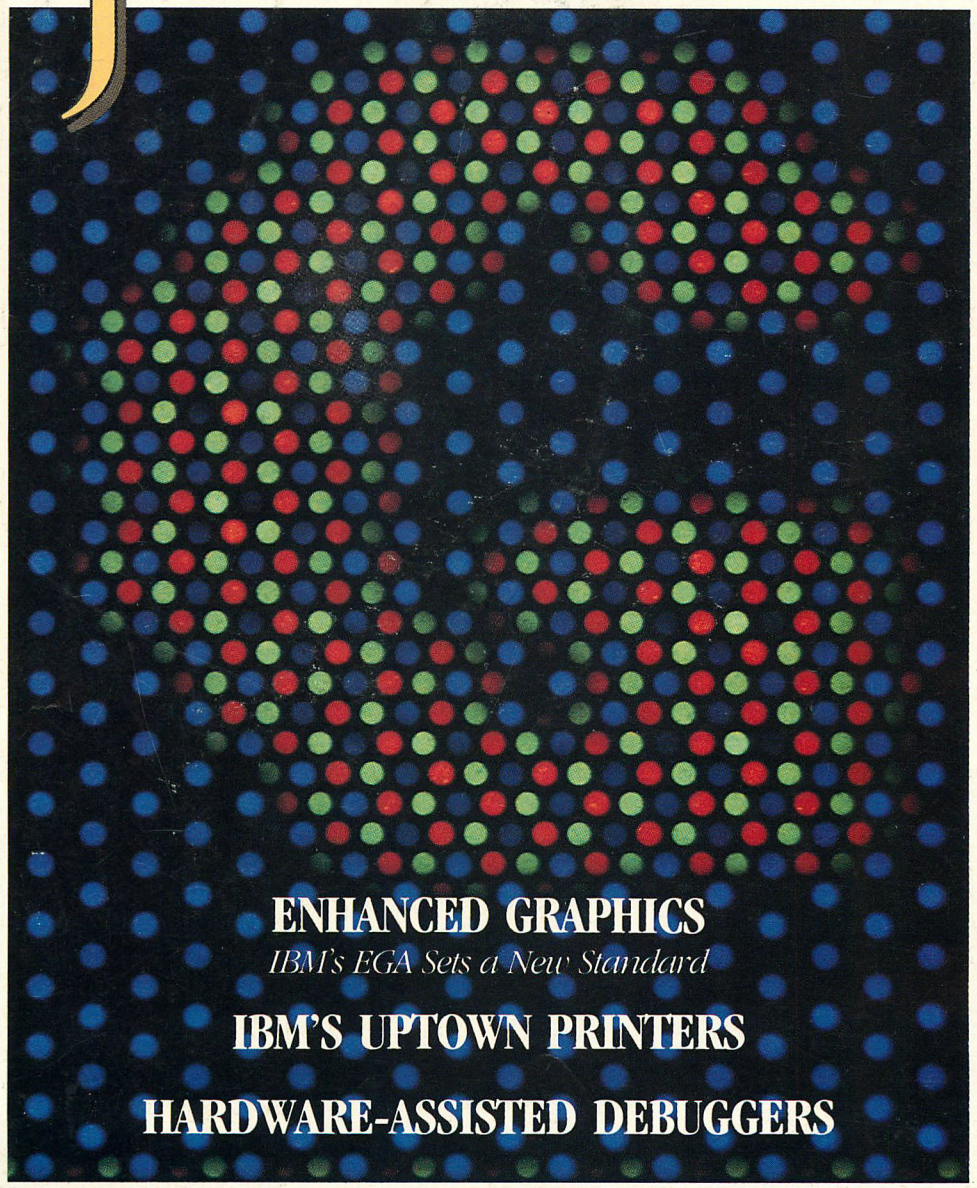
PC TECH JOURNAL



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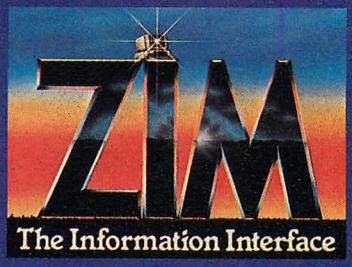

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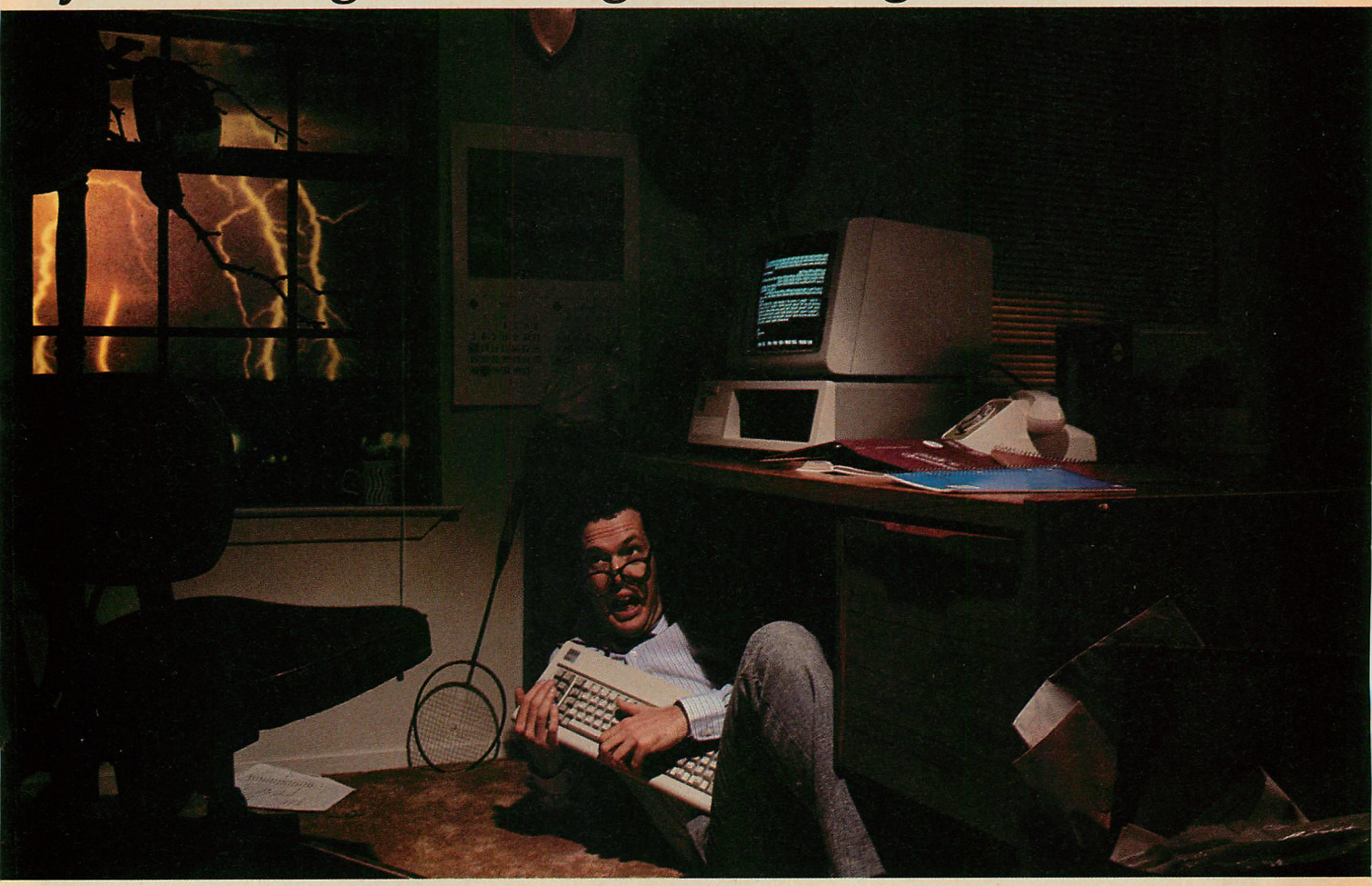

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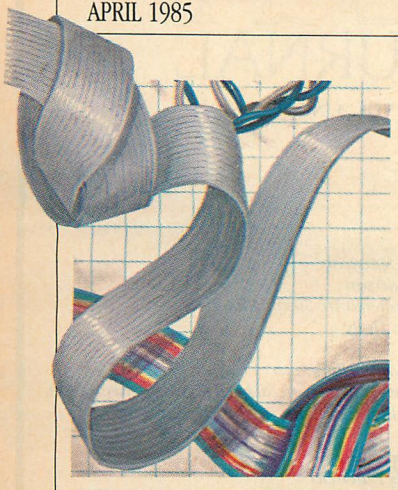

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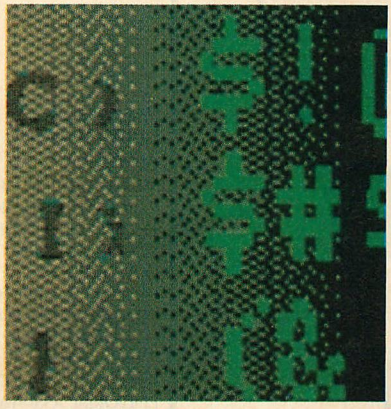

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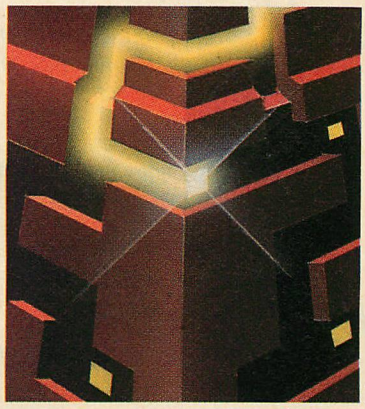

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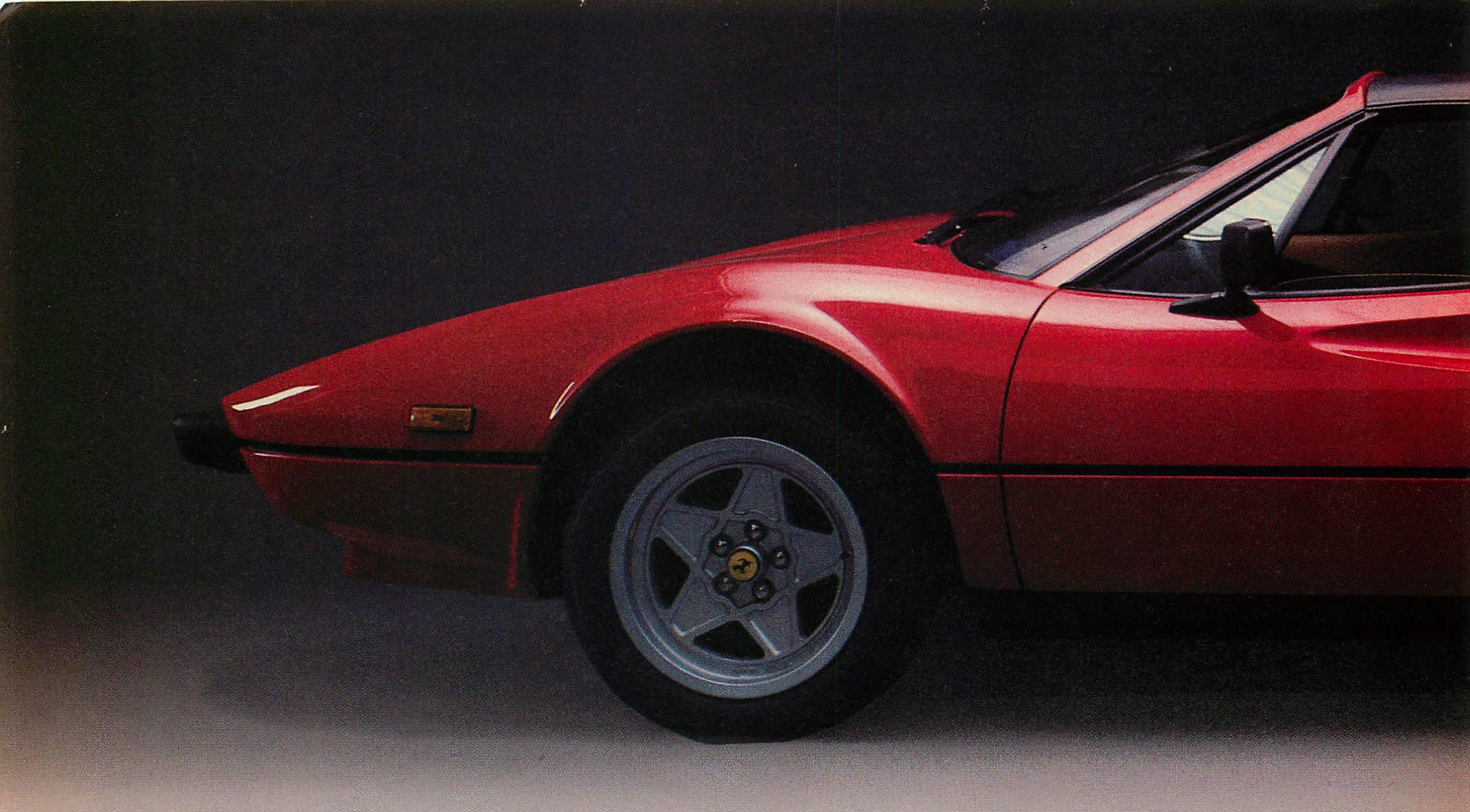

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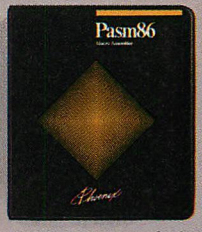

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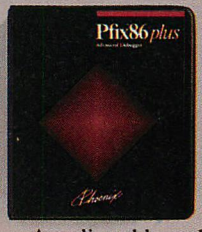

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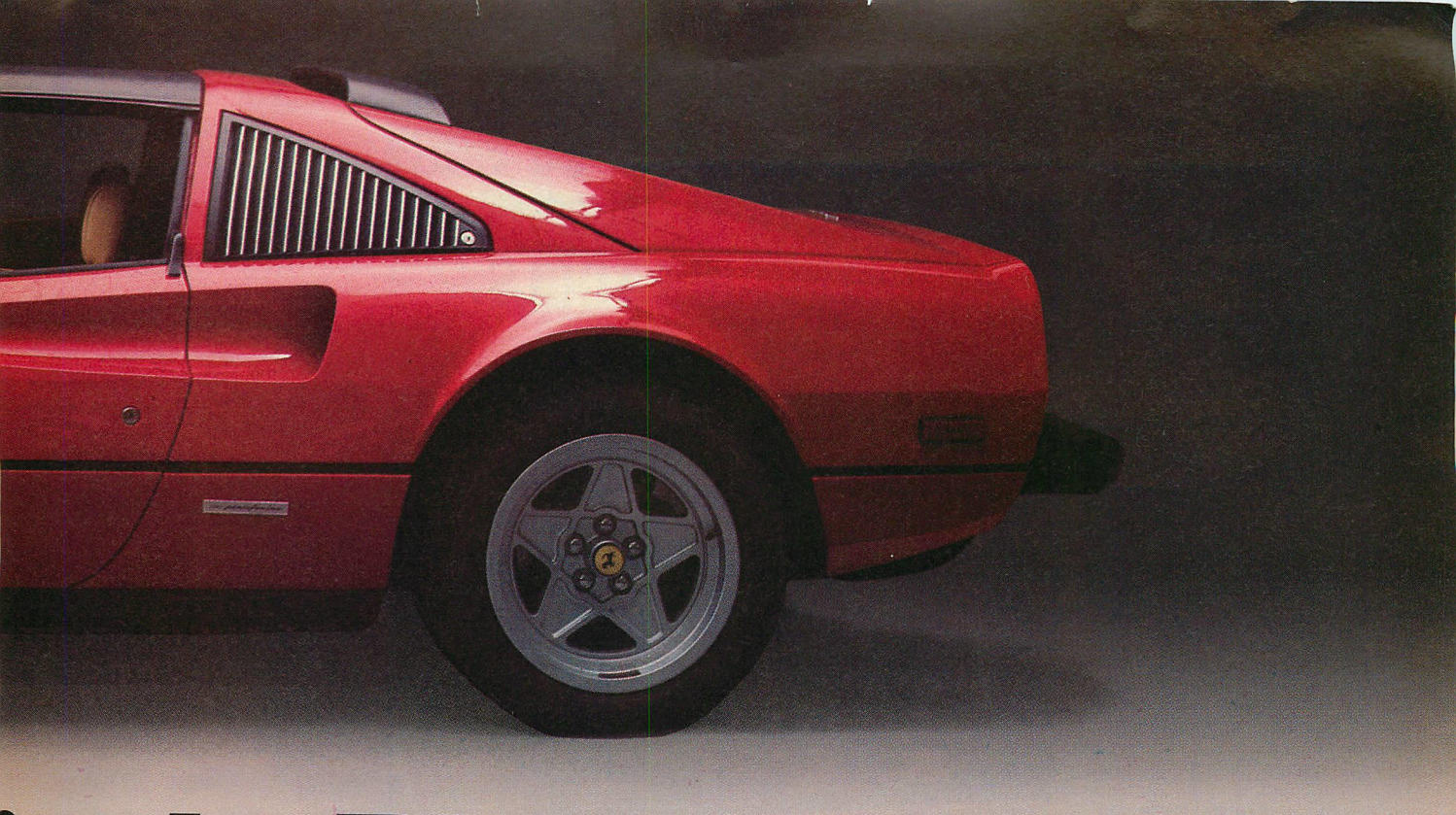

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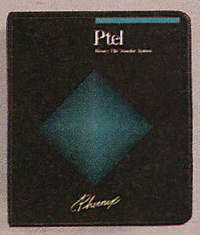

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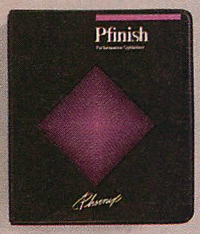

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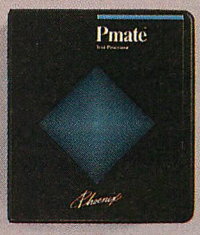

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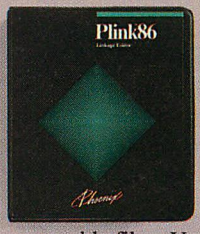

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PC Week/Softsel Top List—December

	BUSINESS	
✓	1 1-2-3	Lotus
✓	2 SIDEKICK	Borland International
✓	3 SYMPHONY	Lotus
	4 DBASE III	Ashton-Tate
	5 MULTIMATE	Multimate International
✓	6 PFS:WRITE	Software Publishing
	7 TAX PREPARER 1985	Howardsoft
✓	8 PFS:FILE	Software Publishing
	9 WORD PERFECT	Satellite Software
✓	10 MICROSOFT WORD	Microsoft
	HARDWARE	
✓	1 SIXPAKPLUS	AST Research
	2 HERCULES GRAPHIC CARD	Hercules
	3 SMARTMODEM 12008	Hayes
	4 SMARTMODEM 1200	Hayes
	5 HERCULES COLOR CARD	Hercules
	6 EXPANDED QUADBOARD	Quadram
	7 MASTERPIECE	Kensington Microware
✓	8 PC MOUSE	Mouse Systems
	9 MODULAR GRAPHICS CARD	Paradise Systems
✓	10 MOUSE	Microsoft
	SYSTEMS & UTILITIES	
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✓	2 TURBO PASCAL	Borland International
	3 CROSSTALK XVI	Microstuf
	4 NORTON UTILITIES	Peter Norton Computing
	5 SIDEWAYS	Funk Software
✓	6 PROKEY	Rosesoft
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	8 SMARTCOM II	Hayes
✓	9 TURBO TOOLBOX	Borland International
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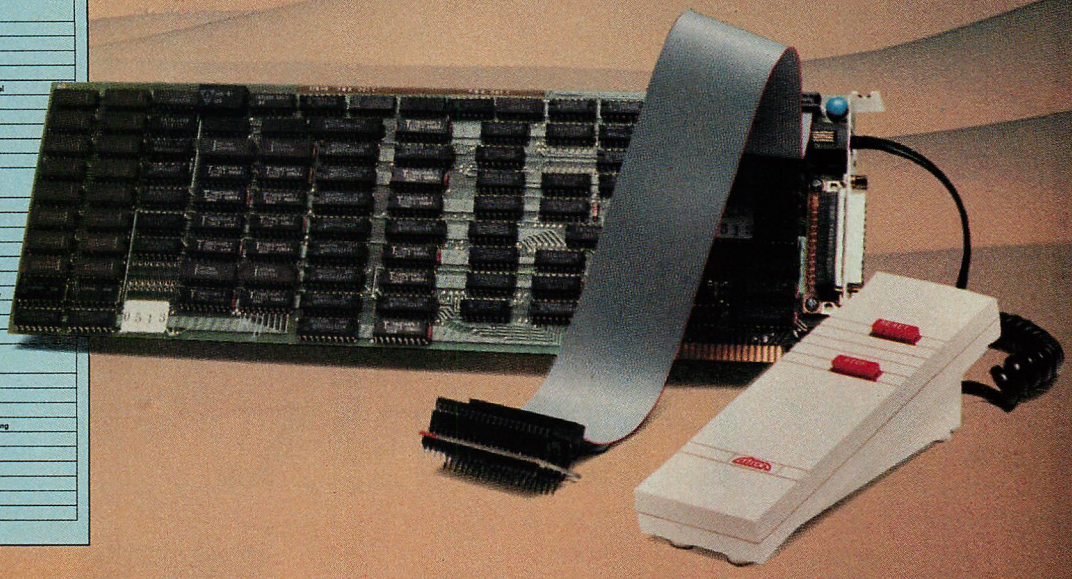

You can't pick up a PC-related magazine without seeing an editorial reference to Borland International's SIDEKICK™ program. It's one of the most popular programs ever sold to PC and PC-compatible users.

FORTUNE magazine talks about Phillip Khan's brilliantly well-executed marketing plan and a well-designed piece of software. All true. But how successful would Borland be if their product weren't absolutely rock solid?

Someone said that if your only tool is a hammer, you tend to treat all problems as if they were nails. While it's certainly possible to hammer out PC products with mere software debuggers, thousands of professionals in hundreds of companies are using Atron debugging tools.

As you can see, thirteen of the top thirty software packages were created by Atron customers. Their hammer: ATRON'S PC PROBE™, a hardware-assisted software debugging tool that plugs into your PC or compatible.

HOW THE PROS DEBUG THEIR SAND CASTLES

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Microsoft Re-emerges

The IBM of microcomputer software companies is back in the driver's seat.

Exactly one year ago, in last April's issue, I spent these pages ruminating about PC/IX (just then announced) and the arrival of the UNIX world at the PC's doorstep. At the time, IBM had endorsed UNIX (or at least embraced it), Digital Research had the mandate for future UNIX development, and Microsoft, for all its early work on XENIX, was effectively out of the spotlight. What a difference a year makes.

Microsoft is squarely back in the spotlight. From my perspective, it is so much in the spotlight that it is casting deep and dark shadows for the other players, even AT&T. What brings Microsoft center stage again is not just XENIX, but an entire strategy that has a good chance of allowing the company to retain its position as the premiere microcomputer software company for a long time to come. Although its strategy is not entirely known, we can speculate.

XENIX-286 is poised to become Microsoft's flagship product, perhaps more important to the company for the future than MS-DOS is today. There is a strong, company-wide commitment to the success of this new operating system. The development status of other Microsoft products also bears this out; many decisions have obviously been made with XENIX in mind.

Microsoft has a good story to tell. Company President Bill Gates speaks of critical mass, the point at which 400,000 installations of UNIX exist (100,000 do today) and UNIX can be said to be a commercial success. Microsoft has begun a series of XENIX-286 seminars for independent system vendors (ISVs) to encourage them to build applications in the XENIX environment and to tell them what kind of support they can expect. A special service, called Microsoft DIAL, has been established to provide such support; although not free, DIAL may help improve Microsoft's reputation for support among smaller ISVs and OEMs, which is mixed, at best.

Three events in the life of XENIX are significant to its success:

1. IBM selected XENIX-286 for private labeling as PC-XENIX, announced with the PC/AT and available now. This establishes XENIX as the de facto standard for the AT.
2. AT&T has announced that it will place the System V XENIX on its price list for the PC6300. It must be a major embarrassment for the owner of a license to buy its product back from a third-party vendor, but this was apparently the only way AT&T could deliver a satisfactory UNIX implementation for its own machine.
3. Microsoft has agreed to upgrade XENIX-286 to the UNIX System V standard from its current status as System III. Furthermore, AT&T has announced its verification and certification program to determine if UNIX implementations comply with the AT&T standard. XENIX is expected to be the first product verified and as such will have an enormous jump on the market.

It looks like Microsoft's long-term investment in UNIX R&D has paid off. Digital Research is out of the picture. We have only to see if Bill Gates' projections for the future hold up. That will require 1 million 286-based machines to be sold in the next 12 months, of which 20 percent must be multiuser systems. Only one company has the potential to build and sell that many machines, and the only question is whether or not IBM actually will.

There can be no question that Microsoft's DOS is an important product. With 3 million installations, MS-DOS is second only to Microsoft's own BASIC interpreter as the most widely distributed software product. It is the de facto standard, and MS-DOS compatibility has become an absolute requirement for any computer built around the Intel 86-family architecture.

MS-DOS has a promising future. For PCs used as single-user, single-task machines, it is the only choice because just about every application expects it. For TopView and Microsoft Windows (see below), it is the base upon which the concurrent operation of tasks is built. In either case, Microsoft's network software (the basis for the IBM PC-Network software) provides access to other services via the LAN. Those categories cover a lot of machines and exclude only serious multitasking environments and terminal-based, multiuser situations.

Microsoft appears to be planning well ahead with MS-DOS. It will admit, if asked nicely, that DOS 4.0 is in the works and that it includes multitasking. On developments beyond 4.0 however —or even regarding the details of 4.0—Microsoft is keeping silent.

MS-DOS/XENIX COMPATIBILITY

Microsoft seems determined not to give up any market opportunity or share for MS-DOS. To cement its position, it is stressing two important points. First, MS-DOS and XENIX are being moved in the direction of execution compatibility. Microsoft claims that a software developer will be able to build an application, obeying minimal rules, that will run in both environments. This means that a single disk with a single program on it will run in either environment. Just consider where the UNIX market would be today if every MS-DOS program ever written could run in XENIX! And consider the savings a vendor might realize in packaging, stocking, and marketing if only one product could be sold. If Microsoft can pull this one off, it will be a heroic deed.

Second, Microsoft is waving the banner for XENIX as the natural habitat of the MS-DOS applications developer. I have to agree. If I were writing a program, I would much rather do it in the sophisticated environment provided by UNIX than in the more rarified atmo-

sphere of MS-DOS. I suppose I can learn to love command names, such as **grep** and **awk** and **cat**, even if those names bear little resemblance to their functions. It's just that kind of function I want when I'm programming.

In the first half of this year, every Microsoft language product will be updated with a major release. In each case, the update is to deliver fundamental improvements to the language products while at the same time providing full compatibility between MS-DOS and XENIX. Versions of the languages will run in either environment, and the XENIX versions will produce code for either system.

The leading edge of this wave of releases is C, a new version of the language developed internally by Microsoft and of which it is obviously proud. A quick check of a few developers who have been using C with the prerelease copies of XENIX (sold to ISVs by Microsoft under special arrangement with IBM) indicates a positive response to the product. *PC Tech Journal* has experimented with a prerelease version of the MS-DOS version and will review the production copy shortly.

Gates has spoken for years about bridging the gap between MS-DOS and XENIX. Developments in the language area are the first, most important, visible sign that the gap is narrowing.

Microsoft is going to become quite competitive in the area of windows, too. Just last month in these pages I wrote about IBM TopView. My thesis was that IBM might try to push its new environment into a new standard. Well, Microsoft Windows may interfere.

Microsoft Windows is a multitasking supervisor that sits over MS-DOS and provides a graphical, icon-based visual interface to the user. As expected, it is operated with a mouse. During a recent visit to Microsoft, I saw the most current version of Windows running on an AT. This, of course, gives a performance advantage, but it was also using a color graphics adapter (CGA), which is a disadvantage. Nonetheless, it looked and ran beautifully.

Microsoft was supposed to have released Windows last fall but delayed the introduction by nine months, to June 1985. It was just about to enter alpha testing when I saw the demo, but it looked very polished and finished to me, notwithstanding one crash.

Microsoft Windows is an important product because it delivers a full graphical display. This capability will enable software developers to build creative new kinds of applications similar to those now being seen on Apple's Macintosh. In fact, Microsoft is going to publish some applications for Mac, and expects the authors to port the programs to the PC and Windows after the Mac versions have been delivered. The developers of Windows say that a Mac programmer will have no problem with the port, because many similar facilities will exist in both environments.

It's a sensational product. If the technical assessment is good, and software developers understand the environment, Microsoft will have a winner.

So there you have it. Except for the current lack of a Windows counterpart in XENIX, all the parts fit together to form a significant, unified thrust into the market. If the products are as good as they seem at first glance, it will be a rare desktop indeed that does not sport a Microsoft operating system, interact via the Microsoft visual interface, or run applications built with Microsoft tools.

OBSERVATIONS ON AN INDUSTRY GATHERING

Julie Anderson, PC Tech Journal*'s executive editor, attended the 1985 Personal Computer Forum in Phoenix January 27-30. More than 450 computer industry experts and watchers were present at the forum, sponsored by Esther Dyson's EDventure Holdings, to discuss issues relating to the software marketplace.*

Apple executives Steve Jobs and John Sculley added color and controversy to the Personal Computer Forum, but this was clearly not an Apple show. The IBM PC was the focus of discussions on applications development, and IBM's market influence was so strongly felt that the remark was made during a workshop on disk drives that the 3½-inch disk has not been standardized in height, power use, or configuration because IBM had not yet announced such a peripheral.

A major topic of discussion centered on how a software developer gets a product to the user. The general consensus was that retailers create bottlenecks; they know only a handful of products to demonstrate to users. It is important to realize, however, that retailers have no vested interest in becoming familiar with every available product. Their responsibility lies in serving their customers, as opposed to the industry as a whole. In reality, they can effectively sell solutions to customers by being thoroughly familiar with only a few good products.

A frustration for developers is a dilemma shared by retailers and end-users alike. The software marketplace is glutted with products—so many that it is almost impossible to distinguish one product's strong points from another's.

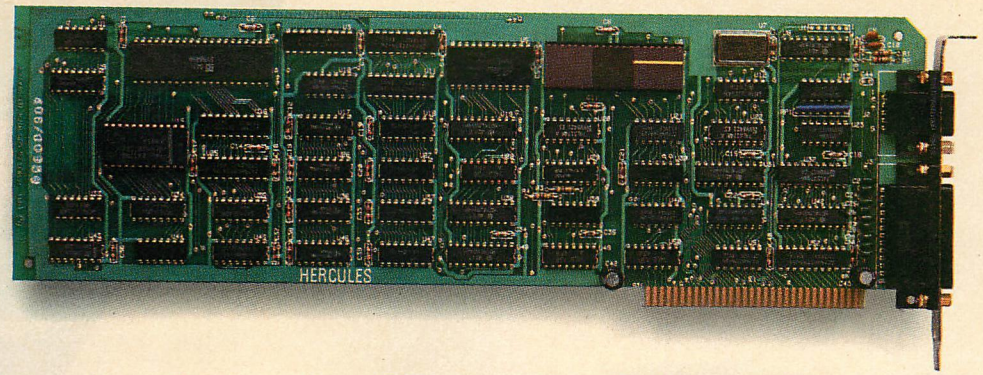
In addition to the overabundance of products is another serious impediment to using a new product: learning a new user interface. A common core user interface is needed. This would be a standard outer shell that would get the user into a program and a standard inner layer that would present the functions of the program in some predefined and agreed upon way. However, each developer must recognize that because people visualize ideas differently, this interface must be flexible and offer the user a choice among a variety of views of the data. IBM's Topview and Microsoft's Windows are moving in that direction.

Another hotly debated topic at the PC Forum was the type of product that should be delivered to users. Unfortunately, *users* are still a vague entity: are they technical or not; are they end users or developers; do they want tools or complete applications? The answer is that there is no universal user. Product opportunities exist across a broad spectrum of users in both vertical and horizontal markets.

A reluctance was apparent among forum participants—except for Bob Berland, director of strategic planning for IBM—to develop for the vertical market. Such applications require a significant investment of time in selling, custom-installing, support, and ongoing enhancement. It is more cost-effective for the developer and retailer to deliver a tool that the user can easily customize to meet individual needs.

Virtually everyone agreed on one point: future success stories like those of VisiCalc, WordStar, or Lotus 1-2-3 will be made with new concepts for products and not with remakes of word processors, spreadsheets, or data managers.

—JULIE ANDERSON



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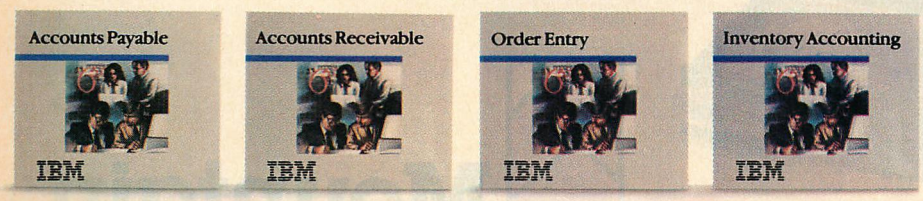

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AUGIE HANSEN

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JAMES CREANE

KERMIT CONFUSION

I would like to like *PC Tech Journal*. It would be a lot easier if you could find a way to stop making egregious technical blunders. In the January issue, for example, you assert on page 61 that 2 to the 10th power is 512. It isn't; as most of your readers (but apparently none of your staff) know, it's 1,024.

Augie Hansen holds a more serious misconception, and repeats it several times in his article on "Kermit" (January 1985, p. 110). The error is his belief that there are computers that "insist on using the high bit of a byte (character) for parity." He repeats it, writing "data cannot be transmitted over data paths that are limited to seven data bits plus a required parity bit." He says it again later in the article, making the error blatant: "Many mainframe systems, including IBM's, require that the high bit in every byte be used for parity."

Hansen is confusing a unit of *storage* with a unit of *transmitted data*. All micros, almost all minicomputers, and most modern mainframes (including IBM's) store data as eight-bit bytes in which all eight bits are significant data.

The units of data sent over a phone line have nothing to do with the eight-bit bytes stored in the computers it connects. There are two conventional character sizes in the TTY-style, asynchronous communications links for which Kermit is designed: seven bits and eight bits. Any computer, including IBM mainframes, may support one or the other or both. Different dial-up ports on the same mainframe may use different character sizes.

Given that the connecting link might limit transmission to seven-bit characters, how can a program send all eight bits of a stored byte? Kermit encodes all types of data as seven-bit ASCII characters so it is able to operate with any link.

Hansen has confused the issue of parity with the other concerns. A communications link may use even parity, odd parity, or no parity bit at all. Any of the six combinations of character size and parity are possible on a Kermit link, but Kermit is concerned only with the character size.

Hansen's article has a further inconsistency. In figure 3, "The Send-Init Packet Data Field," there are references to "char ( )" and "ctl ( )"—functions that are explained nowhere else in the article. This is either the result of sloppy writing or of heavy-handed editing of the author's manuscript.

This is all really inexcusably sloppy for a magazine whose whole purpose for being is its technical content. Sure, ordinary editors can be forgiven for not knowing that $2^{10} = 1{,}024$, and even extraordinary ones might not realize how confused Hansen is about byte sizes. But the magazine as a whole cannot be forgiven. You absolutely must develop some means of ensuring technical accuracy and relevancy. If you don't, I won't bother to renew my subscription.

David E. Cortesi
Palo Alto, CA

In my Kermit article I took the view of computer sytems in the larger sense, including the hardware that lets users make connections with the main computer, whatever it is. My attention was focused exclusively on the communications issues and not at all on data storage within the communicating computers, although my words apparently failed to make that distinction clear.

Most IBM systems in the 370 class use separate front-end equipment (COMTEN 3670, IBM 3705 or 3725, for example). The front ends are usually set to treat the high-order bit of eight-bit received data as a redundant (parity) bit. Unlike UNIX systems, which allow each user wide latitude in how the communications channel is configured for data and parity, these IBM front ends generally cannot be configured by the user, so they are limited to seven-bit ASCII codes plus parity. For efficiency, Kermit prefers to use eight-bit data, no parity when it is available.

The purposes of the char( ) and ctl( ) functions are described briefly in figure 3. I felt that no further detail was needed in the context of the general overview of Kermit. PC Tech Journal*'s editing has never been "heavy-handed" on any of my articles. To satisfy Mr. Cortesi's curiosity, char( ) simply adds 32 (20H) to an integer (0-94) to make it printable ASCII. Because the context is known a priori, a companion function, unchar( ), which subtracts 32 from its argument, can be used to recover the original value after transmission. The ctl( ) function does an exclusive OR of control codes (0-31 or 127) with 64 (40H) to produce a character representation while preserving the high bit. The same function is used to reverse the process. If one were to code this in C, it would be necessary to use tochar( ) instead of char( ) to avoid a conflict with the reserved word* **char**. *These tasks may be handled by the following macros:*

```
#define SPACE    0x20
#define *XMASK  0x40

/*Kermit conversion macros*/
#define tochar(x)   ((x) + SPACE)
#define unchar(x)   ((x) - SPACE)
#define ctl(x)      ((x)^XMASK)
```

Regarding the use of byte and character as synonyms, it is an unfortunate colloquialism that I and other writers should avoid to spare the reader needless confusion. Thanks for the constructive criticism.

—AUGIE HANSEN

Mr. Cortesi is, of course, absolutely right that 2^{10} is 1,024. We regret the error. We are constantly working on ways to improve our editing process to prevent errors such as this from getting into print. Unfortunately, we sometimes miss

one, but we are glad our readers bring them to our attention.

—WF

SIGNIFICANT BUGS

The article, "Significant Figures, III" (Robert Gray, December 1984, p. 187), was very good. I wanted the conversion from ASCII to binary floating point and the binary floating point to ASCII so I could convert them to the 8087 format. To do this I entered the entire listing into my computer so I could get the code tested before I made the modifications (I like to know if the bugs are mine or someone else's).

In order to test these routines I coded a very simple four-function calculator. It requests a number, then an operation, then another number. The program then performs the function and prints the answer.

Of the bugs found, some could have been typos during transcription, but others were program logic errors.

My simple tests were as follows:

```
10 + 10
10 - 10
10 * 10
10 / 10
10 *  0
 0 * 10
10 /  0
 0 / 10
```

My tests were not very extensive, but they found a number of problems. If the article had not been written as well as it was, I would not have tried to debug the program. Without the explanations of the algorithms, I do not think I would have tried to fix this program.

These are the corrections I made to fix the bugs. I used the number 10 because I knew the internal representation of the number. The first test, 10 + 10, gave strange answers. The intermediate results showed that the conversion from binary floating point to ASCII was the problem. Nine instructions after label ASCF5 is the instruction

```
;get address of x from stack
MOV   BX,[BP]+4
```

This should be

```
;get address of x from stack
MOV   BX,[BP]+8
```

The address of x may have been two words back in the stack after the entry, but the routine pushes two more words onto the stack before we get to this point. While I was looking for that bug I looked at the routine INT_F, which is called from ASC_F. INT_F calls RN_F, which did not look correct. The entry to RN_F is as follows:

```
;save index registers
PUSH SI
PUSH DI
;and  BX
MOV  BX,CX
;get operand in DX:AX
MOV  DX,[DI]+2
MOV  AX[DI]
;clear CX
SUB  CX,CX
```

The comments and the code did not seem to make much sense. Looking at other routines I decided that the SUB CX,CX should be the third instruction in the sequence.

```
;save index registers
PUSH SI
PUSH DI
;clear CX
SUB  CX,CX
;and  BX
```

```
MOV BX,CX
;get operand in DX:AX
MOV DX,[DI]+2
MOV AX[DI]
```

I made this change without knowing if this would cause a problem later in my testing. It just made more sense that way, and I did not want to have any more problems than necessary.

The next bug was with 10 − 10. After giving the correct answer my test program did strange things. The binary floating point to ASCII routine checks if the answer is 0, and, if it is, it goes to ASCF11, which is

```
;this will be stored as " 0"
ASCF11:MOV WORD PTR [DI],"0 "
       MOV BX,DI
;offset in BX
       DEC  BX
       JMP  EXIT
```

When we get to this point in the program, DI is pointing to the end of the area to store the ASCII data. The first move instruction will store the blank in the last byte of the field and the 0 in the first byte of the following field. To eliminate destroying the next field I changed the routine to

```
;back up one byte
ASCF11: DEC DI
;this will be stored as " 0"
       MOV WORD PTR [DI],"0 "
;offset in BX
       MOV BX,DI
       JMP  EXIT
```

Now 10 − 10 works correctly.

Then I tried 10 * 10, and it worked. Then 10 * 0, which did not work. The answer shown was −0E−38. That *is* 0, but it should have been just 0. The MUL_F routine checks for either operand being 0; if either one is, it goes to MF2

```
MF2:  JMP FINISH
```

The routine at FINISH expects the answer in DX:AX with the sign in DI. When we go to MF2, the high part of operand one is in DX and the pointer to operand one is in DI. So I changed MF2 to be

```
MF2:  SUB DX,DX
      JMP EXIT
```

EXIT expects the answer in DX:AX and a return code in BX. The entry to MUL_F clears AX,BX,CX, and DX, then loads DX with operand one. If the order of tests were changed from

```
;op1 high word in DX
OR   DX,[DI]+2
;zero only if operand is 0
JZ   MF2
;op2 high word in CX
OR   CX,[SI]+2
JZ   MF2
```

to

```
;op2 high word in CX
OR   CX,[SI]+2
;zero only if operand is 0
JZ   MF2
;op1 high word in DX
OR   DX,[DI]+2
JZ   MF2
```

then MF2 could be

```
MF2:  JMP EXIT
```

I do not know if there are any more bugs, as I have done no other testing than described here. These were very simple tests just to check out the basic operation of the program. Now, please explain to me why you and your authors do not at least (1) compile and do a few simple tests of programs that

you publish; and (2) use the machine-readable listings as input to a typesetting machine. I think that is the least you and your authors can do since your subscribers are paying you to give accurate articles and program listings.

Robert A. Blair
Walnut, CA

Although they are nearly always present in numbers proportional to the size and complexity of the code, errors in published listings are frustrating. Mr. Blair has found several for which I do apologize and for which he has offered workable corrections.

The errors he describes are egregious enough to explain his incorrect conviction that the routines were not tested. My reaction as I read Mr. Blair's letter was one of incredulity, because I had tested the routines. As I reexamined the code, however, I became even more incredulous, for it was clear that the program could not possibly work—yet it passed all of my tests.

I shall explain how this happened, but I should like first to point out that there is a lesson to be learned here. Some programmers, especially those without substantial experience in maintenance programming, seem to hold the conviction that testing is some marvelous tool for the revelation of bugs, and that programs with easily discovered bugs must not, therefore, have been tested at all. This is not the case. Testing is a difficult art requiring time and patience. To test all likely combinations of data that might cause an error is virtually impossible.

An example: I once had responsibility for maintaining a project management system that had been run on a daily basis for about eight years, until it crashed because a major and minor Ctrl-Break occurred at the same time. Now, this is an unlikely event—and one for which the original programmer should have tested. He did not, and the problem did not occur in eight years of continuous use, but it might have occurred the first time the program was run. Then the user would have complained—with some justification—that the program had not been tested.

In this case, I missed an obvious data combination. Although I tested the multiplication routine with a 0 operand, I apparently neglected to test a second 0 operand when the first was not 0. Changing the order of the tests, as Mr. Blair suggests, solves the problem.

Testing is further complicated, as it was here, by the fact that the testing pro-

cedure may actually compensate for errors. For example, the routine at ASCF11 incorrectly stores a 0 in the first byte of the following field, but my driver routine printed the following field with the number so that the output looked fine. More surprising is the instruction MOV BX,[BP]+4 following label ASCF5. As Mr. Blair points out, the displacement should be 8, not 4. Since this instruction picks up the offset of the number to be converted, the routine cannot possibly work, but as the PC Tech Journal *staff can attest, my testing routine works just fine. The reason is simple, but until one encounters the error, not at all obvious. My routine stored the number to be converted at offset 0, and, by coincidence, the value saved at BP+4 also was 0.*

Possibly, the instructions to clear BX and CX at the beginning of the RN_F routine were transposed while I was editing the source file. In any event, to answer Mr. Blair's implicit question, the transposition might cause a rounding error in some cases.

—ROBERT GRAY

UNIVERSAL PROBLEM

We read your article entitled "The Limited Joys of Translated Software" (James Creane, January 1985, p. 142), concerning the conversion of CP/M programs to the IBM PC, with much interest.

In the past, we also experienced many of the same difficulties mentioned in the article. However, we have since introduced a new concept that eliminates these difficulties.

Let me explain the Universal Machine-Independent Assembly Language.

Current assemblers for the various microprocessors use different instruction mnemonics and formats for exactly the same operation. In fact, a single assembler will use several mnemonics for the same basic operation. This not only complicates transferring a program from one computer to another, but makes learning assembly language more difficult. By using a standard or universal set of mnemonics and instruction formats, assembly language is not only easier to learn and use, but also simplifies the process of transferring programs between computers.

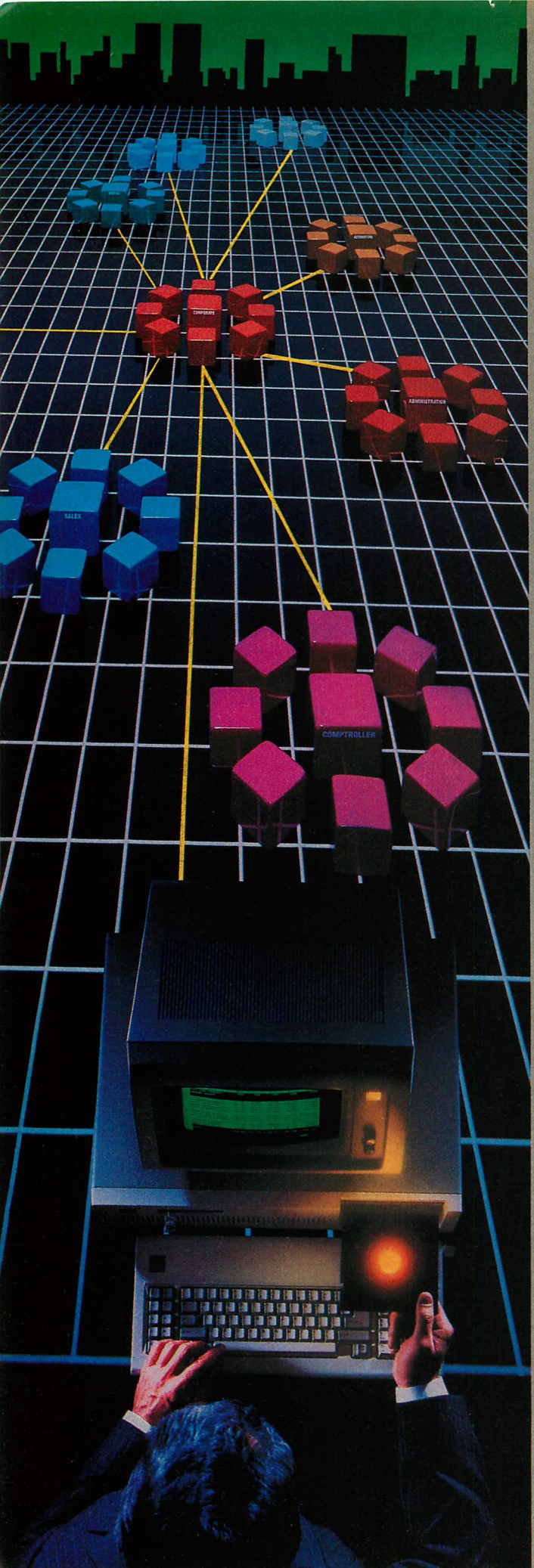
The standard 8080 instruction set includes the following:

```
;load reg A, absolute location
LDA    aa
;load reg A, indirect reg HL
MOV    A,M
;load reg A, indirect reg BC
LDAX   B
;load reg A, indirect reg DE
LDAX   D
```

These four instructions all perform the same basic operation—moving a single byte of data from memory to the A reg, the last three being unique to 8080-type micros. These instructions can be replaced by a single mnemonic using a standard format that is common to all computers and the other move data instructions of the 8080.

```
MOV    A,Abs aa
MOV    A, (HL)
MOV    A,(BC)
MOV    A,(DE)
```

This standard format eliminates the use of two unnecessary mnemonics (LDA and LDAX). Most important is the fact that in converting these instructions to another computer, the most that may have to be changed are the register designators (HL, BC and DE). The use of standard instruction mnemonics and format also makes it easier for someone



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Boasting a data transfer rate in excess of 100,000 BPS, LANLink™ is compatible with a wide range of programs. And because special boards aren't required, installation costs are one-third that of a traditional network.

A Network Designed the Way Business Works. With LANLink™ you're able to customize your network along departmental lines using a data-sharing hierarchy and password-protected access.

Get Started With LANLink™ TODAY. Call The Software Link TODAY for complete details and the authorized dealer nearest you. The LANLink™ Starter Kit, priced at $495, comes complete with network software for both a server and a satellite computer. For a limited time, 50 feet of RS-232 cable will be included free of charge.

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Developers of MultiLink™ and MultiLink Advanced™

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Dealer Inquiries Invited

not fully familiar with a particular processor (8080, for example), but who knows assembly language, to understand a program written for any type of computer.

A large part of any program consists of a few basic procedures. The code required to perform these procedures may vary between computers, but the procedures are the same. A standard set of mnemonics can be used to represent procedures common to all programs. For example, to move a double byte (word) of data from one memory location to another on the 8080, these instructions would be used:

```
;load reg HL
LHLD   aa
;store reg HL
SHLD   aa
```

And in Universal code:

```
MOVVW to,from
```

Not only does this decrease the number of instructions required to write a program and make understanding the program easier, but also, and more importantly, the instruction MOVVW is machine-independent. Procedural-type instructions can be reassembled for execution on any computer without changing the source code.

Complex procedures can be implemented through macro instructions:

```
;convert an ASCII string to a
;single byte value
ATON buf,1th,var
```

This instruction uses the same basic format as any other assembly language instruction and is also machine-independent. The code required to perform the procedure is written as a separate external relocatable subroutine. Unlike with conventional macro assemblers, the assembler can convert the instruction into a call to the subroutine, passing along the parameters, and append the subroutine to the end of the program such that the subroutine itself is included only once.

In effect, what you have is a customized, low-level compiler for which the users can define their own sets of instructions—instructions that are optimized for their particular application and permitting a programmer to write programs in assembly language that are nearly machine-independent.

We have been developing the use of Universal Machine-Independent Assembly Language for the past four years. Although it requires deviation from the computer manufacturer's specified set of mnemonics, a programmer can develop an assembly language program just as fast and with nearly as much transferability as any high-level language, while at the same time, eliminating all high-level-language restrictions.

Last year we started marketing a universal cross assembler for CP/M systems called MOPI, which incorporates these concepts. We are now preparing an improved version for the IBM PC.

We believe that assembly language still has a great future. It was the first programming language and has certain advantages over high-level languages. In fact, for certain applications it is the only language that can be used. Unfortunately, assembly language has fallen victim to circumstances, lack of any uniformity or standardization, bad publicity, and misuse.

Robert M. Fitz
President
Voice Operated Computer Systems
Minneapolis, MN

Introducing

a complete internal half-high 60 megabyte tape backup system for your IBM® PC, XT, or AT for only $995

Complete with tape drive, controller, and software

And it works easily with all IBM compatible operating systems. Simply tell your tape drive you want to backup or restore the entire hard disk, or any file, or backup or restore by subdirectory, date, or everything since you last backed up.

Now you won't have to wait for the difficult to find hard-disk version of the IBM AT (model 99). You can buy the floppy disk IBM AT (model 68), add our hard disk and tape drive system for about what you'd pay for the AT hard disk upgrade alone. It's almost like getting the tape drive free.

Let's face it, we've all heard the horror stories of people who've lost data on their hard disk. True, it doesn't happen often, but then disaster seldom does. With the amount of data you can put on a hard disk these days, no one in business can afford even a small disaster.

When did you last backup your hard disk?

Oh, you did it once with floppies and it was so time consuming that now you've convinced yourself nothing will go wrong? In other words, it can't happen to you. And besides, at the prices they're asking for tape backup—$2,000 and up—you're willing to take a chance. You've seen some tape drives for less, but you have to buy an expensive hard disk to go with it, and you've already got a good hard disk. Where can you turn for relief?

IBM Compatible tape drive system complete for $995

The Express Systems™ tape drive comes complete—half-high tape drive, controller, and software—for only $995. It's absolutely IBM compatible—all 60 megabytes of it.

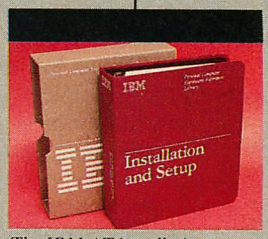
You can use your tape drive in the event your hard disk fails. And if you have to replace your hard disk, the tape's ability to read bad sectors will let you replace your hard disk with another even if the new one is not error-free. The tape requires very low power, too.

And it doesn't poke along. It reads and writes at 90 inches per second (ips) and transfers data at up to 3.75 megabytes per minute in the streaming mode. You don't have to be a rocket scientist to figure that you can perform an image backup of a 20 megabyte hard disk in about 5 minutes. But practically speaking, once you back up your hard disk completely for the first time, you never need to do more than invoke the archive command—that convenient command that tells your new tape drive to back up everything since you last backed up. If you backup as often as you should, your Express Systems tape drive will finish the job virtually in seconds.

The Express Systems software has additional benefits, like enabling you to use PC DOS terminology such as "*", "** *", and "?". It also has a built-in reformatter, built-in verification (to make sure you transferred what you thought you did), and it's prompt driven, which means it asks you exactly what you want to do.

Easy to install

Before you get intimidated about installing our tape drive internally, you should understand that IBM doesn't think it's too difficult. They're selling IBM PC ATs with instructions on how to add additional hard disks in the *Installation and Setup* manual that comes with the AT.



The IBM AT installation manual shows how easily you can install internal storage drives yourself.

Our instructions for installing your new Express Systems tape drive follow IBM's clear, simple instructions.

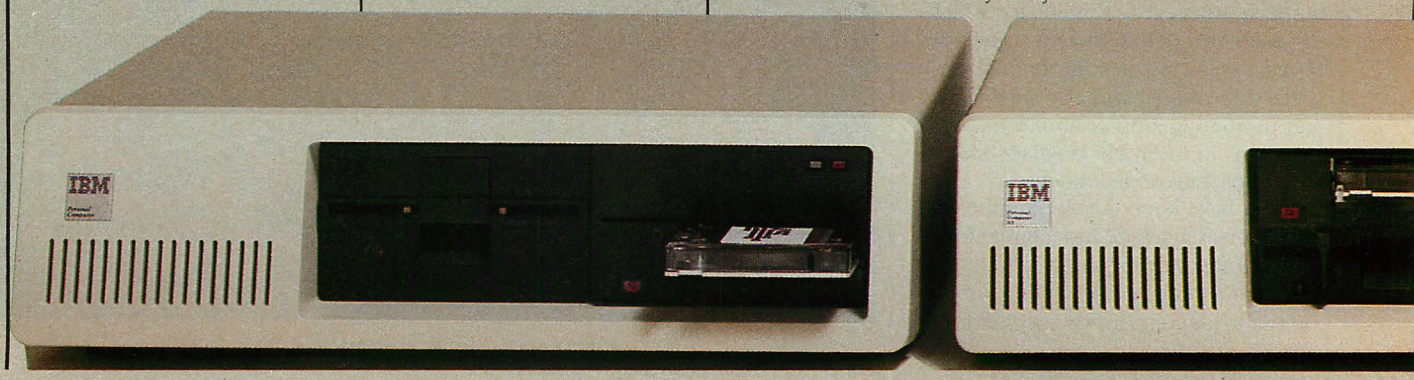
We even provide the tape cartridge

Most people don't realize that the tape cartridge contains most of the critical mechanisms to insure data integrity. In order to be sure that you get the best insurance for your data (after all, isn't that why you're buying it) we encourage you to use Express Systems' specially tested tape cartridges. We're not going to kid you and tell you others won't work, but here's what's special about Express Systems' tape cartridges.

First, they are tested down four separate tracks from end-to-end, not just down the center of the first 150 feet, like some others do. We use three screws to hold the cover on instead of four. This simple triangular arrangement keeps the baseplate flat, just like three legs work better than four to make a table steady. Since all tape drives reference everything to the baseplate, this alignment is critical. We also use special rollers to dissipate posible static electricity buildup—something that can ruin your whole day.

The Express Systems tape drives come with Express Certified™ 555 or 600 ¼-inch tape cartridges with quadruple end-to-end testing for extra insurance of your data.

And finally, we will sell you tape cartridges in boxes of three instead of the usual five. So, you get higher quality with a smaller quantity commitment. And we compound the savings with a lower per unit price, just $35.00 instead of the usual $45.00 most retailers charge.



Need a hard disk?

Depending on whether you have an IBM PC, XT, or AT you may want additional hard disk storage. We have those too. We offer 10, 21 and 31 megabytes of formatted hard disk storage.

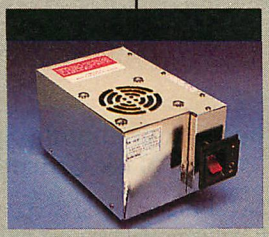
For the most part, our drives are made with plated media, which means there is less chance to damage them. (Let's face it, the oxide that most disks come with is nothing more than rust.) We then test the drives, pre-format them, and install DOS 3.0 so that you're ready to begin transferring files. We even include DOS 3.0 documentation.

Express Systems offers 10, 21, and 31 megabytes of formatted storage in the half-high form so you have extra space for other storage options.

And they're 100 percent IBM compatible. The controller we send you for the XT is an upgraded version of the XT controller from the same company that makes the XT controller. In fact, the Express Systems controller is an improved controller which requires less power so that it is more reliable than any other standard controller.

We provide the power too.

If you want to upgrade your IBM PC, there just isn't any way around upgrading your power supply—if you want to have true XT or better capability. Some companies say that their hard disks don't require any increase in power—and they might be right. But don't add anything to your slots, because the minute you do, you'll need more power. That's the bad news.



Our 130 watt power will convert your PC to XT standards; and it's only $99.50 with any tape drive or hard disk order.

The good news is that our power supplies are inexpensive. How's $99.50 for an XT power supply? We mean a full 130 watts of power. The other good news is that it's held in by only 4 screws. Express Systems' power supplies can be changed in 20 minutes, a small price in time for the peace of mind to convert your PC to an XT-capable machine and avoid the unsightly "wart-like" power supply add-ons that some companies insist you paste on the back of your PC.

Express Systems Upgrade Kits

(Includes controller, software, and cable where appropriate)

IBM AT (model 99) to AT ExPlus™
1 half-high tape drive system — **$995**

IBM XT to XT ExPlus
1 half-high floppy and 1 half-high tape drive system — **$1095**

IBM AT (model 68) to AT ExPlus
21 Megabyte upgrade — **$1895**
1 half-high 21 megabyte hard disk with half-high tape drive system
31 Megabyte upgrade — **$2195**
1 half-high 31 megabyte hard disk with half-high tape drive system

IBM PC to XT ExPlus
2 half-high floppies, 1 half-high 10 megabyte hard disk with controller, 1 half-high tape drive system and 130 watt power supply — **$2095**

But from a mail order house?

We get tired of the snide remarks some people make about mail order houses. The comments are usually spread by distributors and retailers who are getting cut out of 15 and 35 percent margins, respectively. If we went through distribution—you'd have the privilege of paying for large glass windows, rugs, salesmen, etc.—but we'd also be selling this tape drive for $1495.

We're not criticizing distributors and retailers. They perform a valuable service. But you don't need them if you know what you want. And you can certainly install it yourself. IBM has proved it with their instructions for self-installation that come with the new IBM PC AT.

And speaking of IBM, the next time you hear anyone criticize mail order as a way to buy computer equipment, remind them that IBM is now in the mail order business.

Warranty

We offer you a one year warranty on our hard disks—the same as IBM on the AT and 90 days on the tape drives. (It's all the manufacturer gives us.) If anything goes wrong with your tape or disk drive or hard disk, send it back in the box it came in. However, we have found that we can usually solve the problem over the phone. So call first for a return authorization number because we can't accept any returns without it.

Immediate delivery

We have four types of delivery: *Next Flight Out*℠ if you need it immediately: *Next Day Express*℠ and *Day After Tomorrow*℠ if you can wait a day or two; and our normal delivery—which we pay—if you can wait a few days.

Express Systems Product Line

Internal Tape System
Half-high tape drive, controller, & software — **$995**

Tape Subsystem
Tape system, controller, power, supply, cable, and chassis — **$1195**

Internal Tape & H.D. System
Tape & hard disk internal systems come complete with tape controller and hard disk controller, software, and cables. Hard disks are formatted and tested with DOS 3.0.

Tape drive & 10 MB H.D.	**$1695**
Tape drive & 21 MB H.D.	**$1895**
Tape drive & 31 MB H.D.	**$2195**

Hard disks Kits
(includes Controller and cable)

10 megabyte hard disk*	**$695**
21 megabyte hard disk*	**$995**
31 megabyte hard disk*	**$1395**

**Subtrack $195 for IBM AT which does not require hard disk controller*

Controllers
Hard disk controller — **$195**

Floppy Disk Drive
Half high floppy disk — **$129**

Power Supply
130 Watt XT replacement Power Supply — **$99.50**
(Price valid only with purchase of tape drive or hard disk. Otherwise, $149.95)

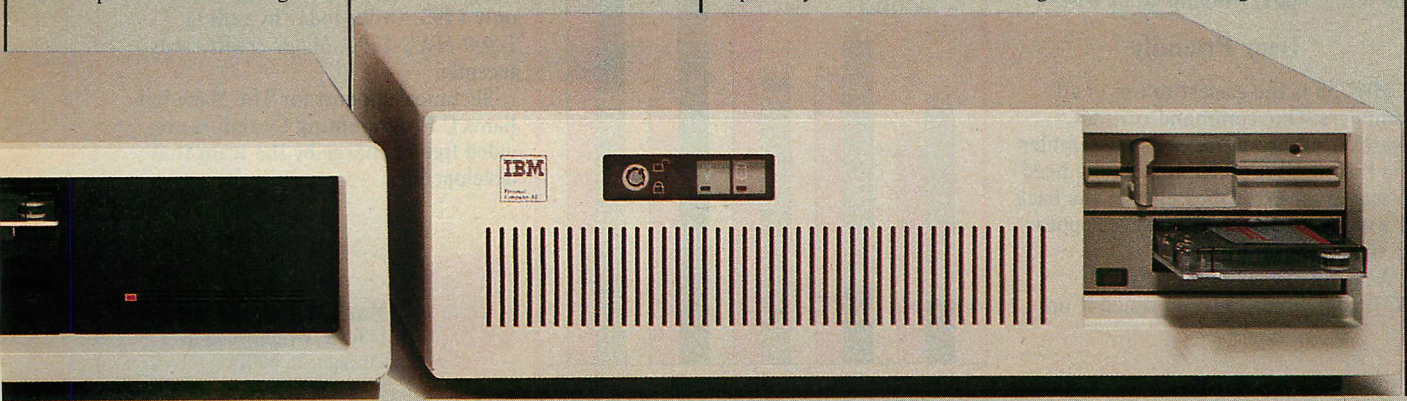
Tape Cartridges
Express Certified 555™ — **$35.00**
(555 feet of specially tested 310 Hci tape)
Express Certified 600™ — **$35.00**
(600 feet of specially tested 550 Hci tape)

How to order

Pick up the telephone and call 1-800-341-7549, to order. We accept Master Card, VISA, American Express and Diners Club. Or send a cashier's check or money order (We'll take a check, but you'll have to wait for it to clear) and tell us if you want one of our recommended configurations or you want to mix and match yourself. Corporations with a DUNS number may send purchase orders for quantities over five.

EXPRESS SYSTEMS

Call Toll Free 1-800-341-7549 Ext. 100
In Illinois call (312) 882-7733 Ext. 100
Express Systems, Inc., 1254 Remington Rd., Schaumburg, IL 60195



Available for IBM PC

What C did for Programming
Mark Williams has done for C Programming

The C Programming System from Mark Williams

MWC86 gets your C programs running faster and uses less memory space than any other compiler on the market. Then *csd*, Mark Williams' revolutionary C Source Debugger, helps you debug faster. That's The C Programming System from Mark Williams Company.

MWC86

MWC86 is the most highly optimized C compiler available anywhere for the DOS and 8086 environment. The benchmarks prove it! They show MWC86 is unmatched in speed and code density.

MWC86 supports large and small models of compilation, the 8087 math coprocessor and DOS 2.0 pathnames. The compiler features common code elimination, peephole optimization and register variables. It includes the most complete libraries. Unlike its competition, MWC86 supports the full C language including recent extensions such as the Berkeley structure rules, voids, enumerated data types, UNIX* I/O calls and structure assignments.

Quality is why Intel, DEC and Wang chose to distribute MWC86. These industry leaders looked and compared and found Mark Williams to be best.

User Friendly

MWC86 is the easiest to use of all compilers. One command runs all phases from pre-processor to assembler and linker. MWC86 eliminates the need to search for error messages in the back of a manual. All error messages appear on the screen in English.

A recent review of MWC86 in *PC World*, June, 1984, summed it up:

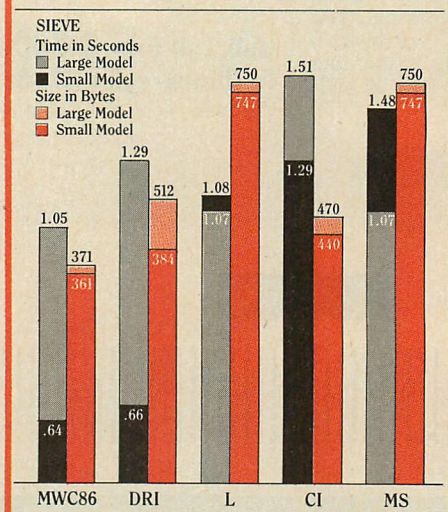
"Of all the compilers reviewed, MWC86 would be my first choice for product development. It compiles quickly, produces superior error messages, and generates quick, compact object code. The library is small and fast and closely follows the industry standard for C libraries."

csd C Source Debugger

Mark Williams was not content to write the best C compiler on the market. To advance the state of the art in software development, Mark Williams wrote *csd*.

csd C Source Debugger serves as a microscope on the program. Any C expression can be entered and evaluated. With *csd* a programmer can set tracepoints on variables and expressions with full history capability and can single step a program to find bugs. The debugger does not affect either code size or execution time. *csd* features online help instructions; the ability to walk through the stack; the debugging of graphics programs without disturbing the program under test; and evaluation, source, program and history windows.

csd eases the most difficult part of development — debugging. Because *csd* debugs in C, not assembler, a programmer no longer has to rely on old-fashioned assembler tools, but can work as if using a C interpreter — in real time.



The C Programming System from Mark Williams now supports the following libraries:

Library	Company
Windows for C	Creative Solutions
Halo	Media Cybernetics
PHACT	PHACT Associates
The Greenleaf Functions	Greenleaf Software
Btrieve	SoftCraft

The C Programming System from Mark Williams

The C Programming System from Mark Williams delivers not only the best C compiler for the 8086 but also the only C source level debugger. That's why it does for C programming what C did for programming. The Mark Williams C Programming System gives the programmer the MWC86 C compiler and the *csd* C Source Debugger for only $495. Order today by calling 1-800-MWC-1700. Major credit cards accepted.

Technical support for The Mark Williams C Programming System is provided free of charge by the team that developed it.

Mark Williams Company
1430 W. Wrightwood Ave.
Chicago, IL 60614

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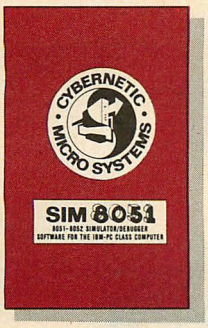
*Unix is a Trademark of Bell Laboratories.



Sim8051

An inexpensive simulator for the 8051 performs well on the PC—with no additional hardware.

While it may be difficult to imagine an 8051 simulator that runs on the IBM PC without requiring additional hardware, that is exactly what Cybernetic Micro Systems, Inc. offers in the Sim8051, this month's *PC Tech Journal* Product of the Month.

For the software developer, the simulator is an inexpensive alternative to expensive in-circuit emulation hardware. Sim8051 is an interactive debugger that runs Intel hex format files produced by the CYS-8051 cross assembler on the IBM PC. Upon execution of Sim8051, the program displays a complete menu of available commands, some reserved for future use, and requests the hex file name to be loaded. When the file name is entered (no extension is required), the program loads the hex file and the listing file. If the listing file cannot be found, an error message is generated. It then divides the screen into three windows, as shown in the photo: one lists past, current, and future code in assembly mnemonics; one displays the current register bank, I/O ports, PC, DPTR, ACC, PSW, and, alternately, the cycle counter and timer values or the register select bits and the interrupt edge flags; one displays a flow chart derived from markers in the listing file. Another small window at the bottom left shows the currently selected memory segment. The stack is displayed in the center of the screen, dynamically increasing and decreasing when executing 8051 code.

Control commands and one-letter commands allow full manipulation of the program memory, internal data memory, external memory (up to 256KB), special function registers, and I/O ports. Program execution can be simulated with the single step, auto step, go, or execute commands. Single-stepping is implemented by simply pressing the space bar. When using auto step, the stepping rate can be changed by executing the appropriate command. The go command allows the user to go from any valid address to any other valid address. Execute instructs the simulator to run at the maximum execution rate. Breakpoints can be set at any address in the range of 0 to 0FFFFH with no apparent limitation.

Traps can be set to detect whether a register or memory location is equal to, less than, or greater than a value and to monitor all three conditions, using a different value for each test. A trap for all of the registers can be set simultaneously, but only one memory location can have a trap set at any time.

The facility for tracing program flow is also available by enabling the trace mode. Trace is terminated when the instructions specified have been executed or when the user presses the space bar.

Interrupts are handled by the simulator in the same fashion as on the 8051. By changing the value of pins 12 and 13 (INT0 and INT1), interrupts can be generated to test the interrupt service routine. Interrupts can also be forced, oblivious to the state of the interrupt-enable or interrupt-priority registers with the forced interrupt command. The interrupt service routines tend to be time-critical. The cycle counter can be a useful tool when simulating time-critical routines because it is directly related to the crystal oscillator.

When the program gets lost and the simulator seems in disarray, the initialize command can simulate a hardware reset by pulling pin 9 high and returning it low. Other convenient commands include a hexadecimal calculator for addition and subtraction; return from a subroutine to exit prematurely from a subroutine and maintain stack integrity; and a clear screen command when a fresh start is in order.

For the serious 8051/52 software developer, Sim8051 is an economical alternative to an ICE51 or an EMV51. For less than $600, software can be developed and tested for any 8051/52-based product on the PC.

Sim8051, version 1.0, was used to select Product of the Month. Since then, Cybernetic has released version 2.0.

—WF

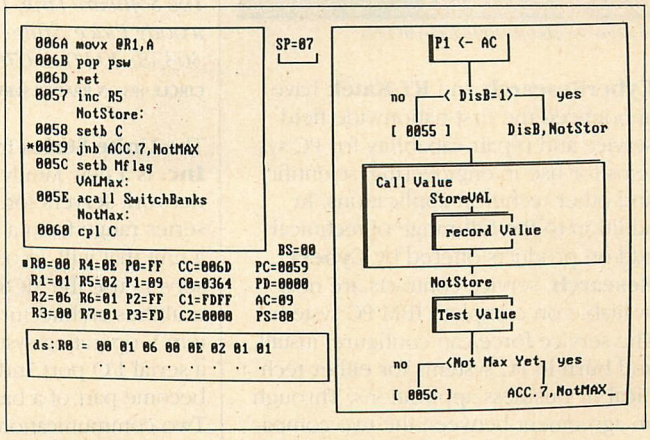
PRODUCT NAME
Sim8051

COMPANY
Cybernetic Micro Systems

ADDRESS
P.O. Box 3000
San Gregorio, CA 94074

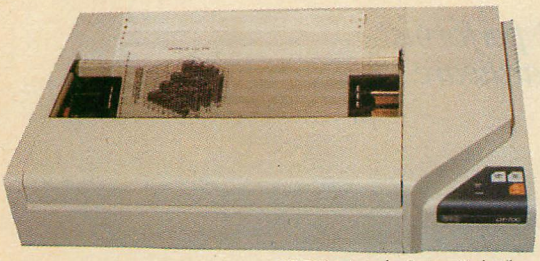
TELEPHONE
415/726-3000

PRICES
Sim8051: $595
Also available for the same price is a simulator for the 8048, the Sim8048.



Sim8051 divides its screen into three windows.

Hardware, software and other developments for the PC

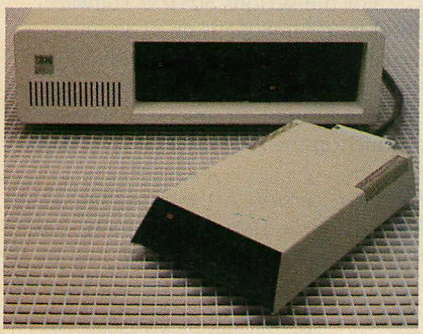


OT-700 printer by Output Technology

PC SHADOW

HARDWARE

Peachtree Peripherals, Inc. has introduced a **10MB External Drive** for the PC/XT. The drive uses a hard carbon-coated platter surface that provides media that is up to three times as durable as a standard ferrous oxide disk such as is used in the XT's drive. It can be used as a back-up 10MB drive (with complete random access) or as an additional 10MB of on-line storage. Because it uses the existing controller card, no other expansion slot is needed. The drive requires no software support and is compatible with all DOS utilities (version 2.0 or later). $895.
Peachtree Peripherals, Inc., Technology Corporate Campus, 3159 Campus Drive, Norcross, GA 30071; 404/446-3222
CIRCLE 494 ON READER SERVICE CARD



Peachtree Peripherals' 10MB External Drive

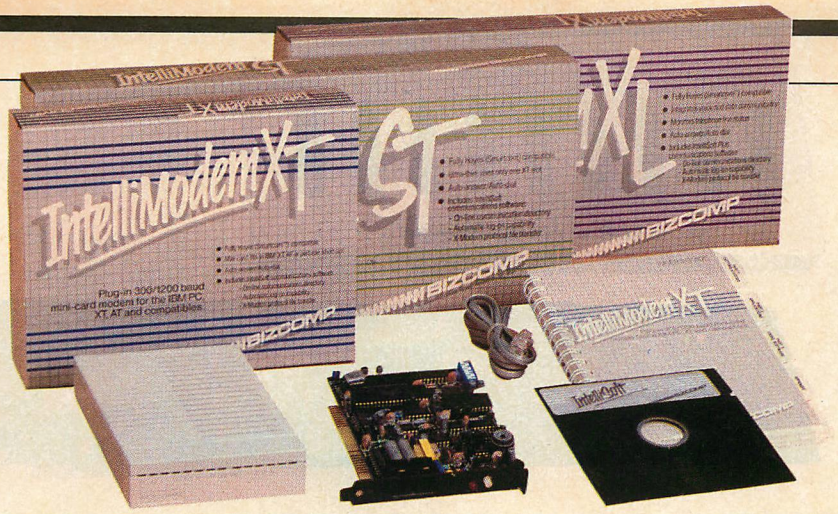
CyberResearch and **RT/Katek** have announced the first nationwide field service and repair capability for PC systems for use in engineering, scientific, and other technical applications. In addition to the full range of technical add-on products offered by **CyberResearch**, service contracts are now available on complete IBM PC systems. The service force can configure, install, and burn-in PC systems for either technical or business applications. Through an agreement between the two companies, products can be serviced from more than 270 service locations with 1,300 technicians in all 50 states. Four-hour response time is provided on the PC and standard peripherals. Technical add-on replacement parts can be distributed air express to provide next day service response. A single blanket service contract can now cover complete business engineering or production PC systems in a company. The product categories supplied by CyberResearch for which nationwide field and repair service is available include data acquisition, instrument control, computer-aided design, presentation graphics, and three-dimensional modeling. Service prices according to product configuration.
CyberResearch, Inc., 5 Science Park Center, P.O. Box 9565, New Haven, CT 06536; 203/436-2600
CIRCLE 481 ON READER SERVICE CARD

An IBM look-alike terminal called **PC SHADOW** has been announced by **The Software Link, Inc.** The new monochrome CRT has a 25-line screen and an IBM-style keyboard. It will support IBM graphics characters and IBM screen attributes, such as reverse video, highlighting, blinking, and low intensity. It supports the auxiliary printer port with a transparent data path that uses the XON/XOFF protocol. $895.
The Software Link, Inc., 8601 Dunwoody Place, Suite 336, Atlanta, GA 30338; 404/998-0700
CIRCLE 493 ON READER SERVICE CARD

The **Unite Series** from **CYB Systems, Inc.** is a new family of UNIX-based network servers for PCs. Models in the series range from a single-server unit to a unit that will accommodate 32 PCs. All servers use the MC68000 processor, multibus architecture, and the UNIX System V operating system. A PC must have a serial I/O port and 192KB of RAM to become part of a basic Unite network. Two communications speeds are available: 9600 baud using twisted-pair wire and 10 megabits per second using EtherNet (an optional EtherNet controller is required by Unite and each PC). Users of PCs in a Unite network may either run applications in PC-DOS or log into Unite as a terminal and use that system's processor to run UNIX applications. Units are priced from less than $9,000 to more than $35,000.
CYB Systems, Inc., 6448 Highway 290 East, D-111, Austin, TX 78723; 512/458-3224
CIRCLE 488 ON READER SERVICE CARD

The TeamMate division of **Data Technology Corporation** has announced **models 1120AT** and **1132AT**, two new data storage products that are designed to fill users' immediate needs for enhanced IBM PC/ATs. The two products, which will plug into the AT's existing controller, consist of preformatted drives, cables, installation guides, slides for mounting the machine, and a copy of InfoTools' Bakup back-up management software package. Model 1120AT provides 20MB of storage; model 1132AT provides 32MB. Model 1120AT, $1,295; Model 1132AT, $2,495.
TeamMate, Data Technology Corp., 2775 Norwestern Parkway, Santa Clara, CA 95051; 408/496-0434
CIRCLE 487 ON READER SERVICE CARD

A 700-character-per-second (cps) dot-matrix printer that features a new print head technique to achieve high speed and high reliability has been unveiled by **Output Technology Corporation**. Designed for both micro and minicomputer users, the model **OT-700** printer offers correspondence-quality printing at 350 cps and dot-addressable graphics capability. Targeted to meet high-volume output needs of data processing environments, the OT-700 has no duty cycle limitations. Both centronics parallel and RS-232 serial interfaces and a 4KB buffer are offered as standard features. For applications flexibility, numer-



BIZCOMP's INTELLIMODEM Series

ous character sets for foreign languages are offered. Machine configuration is easily accomplished via menu-driven program commands. The unit offers full 136-column carriage width with adjustable sprocket-feed tractors. Paper feed is from the front or bottom of the case. The printer's control panel features state-of-the-art membrane switches and LED indicator lights. $1,795.
Output Technology Corporation, 606 110th Avenue, NE, Suite 205, Bellevue, WA 98004; 206/453-9794

CIRCLE 477 ON READER SERVICE CARD

PRIAM CORPORATION has announced that its **PRIAM DataTower** add-on mass storage and back-up system now can be connected easily to the basic PC/AT to supplement that system's storage. Available in 75MB and 160MB capacities, the DataTower is a free-standing unit containing an 8-inch Winchester disk drive and a high-speed streaming tape back-up device. In data-intensive applications requiring even more storage, PRIAM offers the **ExpansionTower**, which can be daisy-chained to the DataTower. The ExpansionTower contains either one or two 8-inch Winchester disk drives, adding from 75 to 320MB of storage. Prices: DataTower, $895; contact PRIAM for pricing on ExpansionTower.
PRIAM Corporation, 20 Montague Expressway, San Jose, CA 95134; 408/946-4600

CIRCLE 479 ON READER SERVICE CARD

PRIAM's DataTower

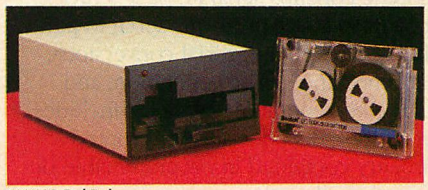
BIZCOMP has announced its new three-product family: the INTELLIMODEM Series. This series includes the **INTELLIMODEM XL**, the **INTELLIMODEM ST,** and the **INTELLIMODEM XT**. All three plug-in modems are 300/1200 baud, auto-answer/auto-dial; include INTELLISOFT communications software; have unlimited on-line telephone directories and XMODEM error-checking protocol file transfer; operate in full or half duplex; and are 100 percent Hayes-compatible. The INTELLIMODEM Series is based on proprietary digital signal processing requiring only a single microprocessor and a single crystal. By putting the command set, modulation, and significant portions of the demodulation within firmware, far fewer components are required.

The INTELLIMODEM XL operates in dual-command mode—the user can choose data transmitted only, using virtually any communications software package written, or he can use the shared voice and data feature. The INTELLIMODEM ST implements the Hayes Smartmodem 1200 command set precisely. The INTELLIMODEM XT has all the advanced features of the ST with the added benefit that it is a mini-card that will fit into all the short slots of the PC/XT, PC/AT, and the IBM Portable. INTELLIMODEM XL, $549; INTELLIMODEM ST, $499; INTELLIMODEM XT, $549.
Bizcomp, 532 Mercury Drive, Sunnyvale, CA 94086; 408/733-7800

CIRCLE 475 ON READER SERVICE CARD

Variant Technologies, Inc. has announced two new tape storage systems. The **Model VT-500 XT**—or **BakPak**—is designed to function with the PC or PC/XT, and the **Model VT-500 AT**—or **BakPak II**—is designed for use with the PC/AT. Both tape systems support DOS 2.0, 2.1, or 3.0. The systems provide 26MB of formatted data storage using industry-standard DC600A tape cartridges. The host adapter fits in the short slot of the XT. The systems come with menu-driven utilities that allow back-up and restoration by file, volume, or physical device. Data integrity is achieved through a CRC checking algorithm. The defect-mapping function reserves all bad blocks on the data cartridge. BakPak, $995; BakPak II, $1,095.
Variant Technologies, Inc., 16129 Wyandotte Street, Van Nuys, CA 91406; 818/904-9780

CIRCLE 484 ON READER SERVICE CARD



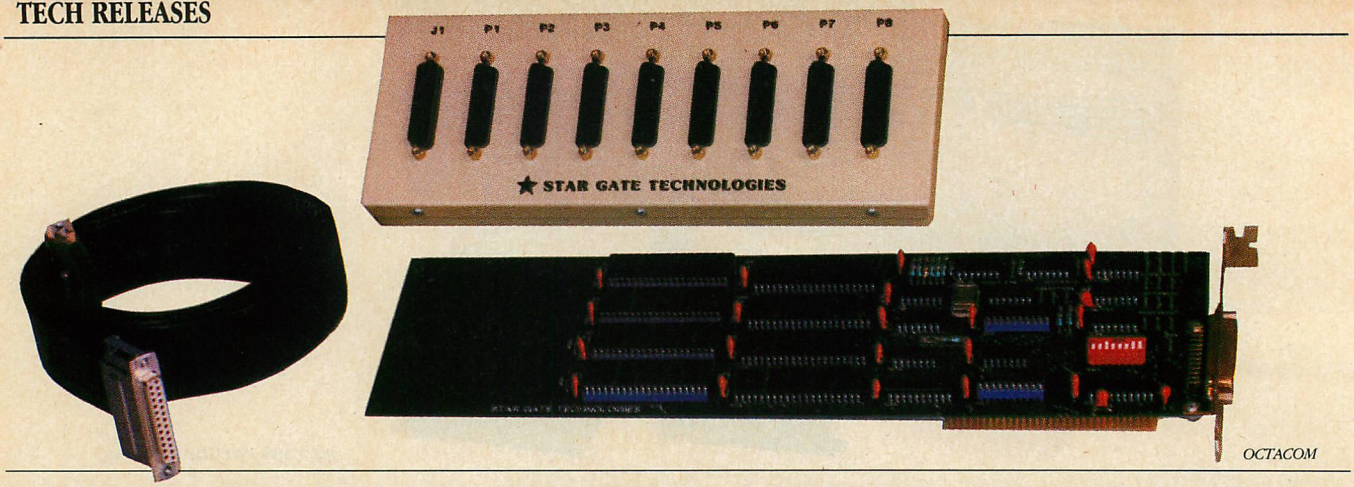
VT-500 BakPaks

Rancho Technology has introduced **QUIET X-TEND**, a low-noise extender card for the PC, PC/XT, and PC/AT. The product allows development and test engineers to monitor and debug their printed circuit card designs in the PC without injecting noise or voltage drops. QUIET X-TEND is a four-layer card with power supply decoupling. All signals are labeled with the pin number and signal mnemonic. Remote power supplies can be used for voltage margin testing. $125.
Rancho Technology, 10238 Monte Vista Street, Rancho Cucamonga, CA 91701; 714/987-3966

CIRCLE 490 ON READER SERVICE CARD

All the networking hardware and drivers required to run **Microsoft Networks (MS-NET)** on IBM PCs are now provided by **Nestar Systems, Inc.** Nestar products work with all MS-NET components, including the redirector and file server. Interface cards, cables, and hubs for linking PCs into an MS-NET system are provided. Nestar has added a full implementation of MS-NET to the company's PLAN 2000 network. $595.
Nestar Systems, 2585 East Bayshore, Palo Alto, CA 94303; 415/493-2223

CIRCLE 489 ON READER SERVICE CARD



OCTACOM

OCTACOM, from **Star Gate Technologies**, is a flexible adapter board with multiple serial communications ports. The board adds four, six, or eight serial ports to the PC or PC/AT and can be installed in any slot. Designed for use with IBM's XENIX for the PC, OCTACOM can also be used with PC-DOS in many applications, if the OCTADRIVE software device driver is used. The OCTACOM module contains separate 8250 UARTS; each 8250 UART performs serial-to-parallel and parallel-to-serial conversions, data checking, parity generation, and baud-rate generation. OCTACOM includes an address decoder and interrupted circuitry contained in programmable devices that allow the user to customize the product for his configuration. The interrupts for each of the eight channels on OCTACOM may be programmed to send an interrupt to the CPU on any free interrupt level. Prices: four-channel model, $295; six-channel model, $345; eight-channel model, $395.
Star Gate Technologies, P.O. Box 764, Cleveland, OH 44026; 216/292-5390

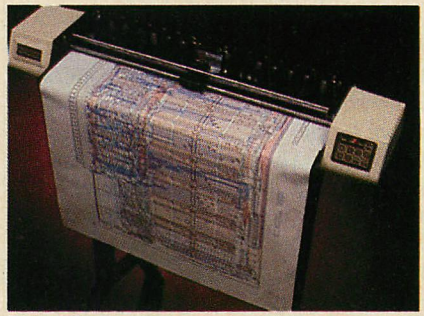
CIRCLE 492 ON READER SERVICE CARD

A new SCSI-IBM PC host adapter has been introduced by **Advanced Storage Concepts, Inc.** The **ASC-88** connects the PC, PC/XT, PC/AT, and compatibles to the expanding range of disk, tape, and other products that employ the SCSI interface. The adapter is a full implementation of the SCSI bus interface standard, featuring arbitration, disconnect/reconnect, and hardware compatibility with a new proposed SCSI extension that permits as many as 64 devices on the bus. It supports overlapped disk operations. Software is provided by an ASC-BIOS PROM that enables direct emulation of fixed-disk BIOS commands. Priced at approximately $250.
Advanced Storage Concepts, Inc., 9660 Hillcroft, Suite 325, Houston, TX 77096; 713/729-6388

CIRCLE 485 ON READER SERVICE CARD

The **51/52 MP** from **Houston Instrument** is a 14-pen DMP-51/52 MP plotter that features a resolution of .001 inches, a maximum plotting speed of 22 inches per second, and a user-selectable acceleration rate of up to four g's. The C- and D-sized plotter also includes constant velocity control to ensure uniform inking regardless of the angle of pen movement and an automatic self-capping feature to prevent pens from drying out. The plotter is compatible with more than 200 software programs and can be interfaced with any computer featuring an RS-232 port. $5,995.
Houston Instrument, P.O. Box 15720, Austin, TX 78761; 512/835-0900

CIRCLE 482 ON READER SERVICE CARD



DMP-51/52 MP

Three new **hard-disk drives** for the IBM PC/AT have been introduced by **Mountain Computer, Inc.** The 20, 35, and 120MB drives give the basic PC/AT the storage capacity of the enhanced AT. Installation can take as little as ten minutes. They use the AT's disk controller and power supply, and require DOS 3.0. One or two drives may be installed internally. Mountain offers internal tape back-ups that can install in the second floppy drive position. Prices: 20MB drive, $1,995; 35MB drive, $2,795; 120MB drive, $9,590.
Mountain Computer, Inc., 300 El Pueblo Road, Scotts Valley, CA 95066; 408/438-6650

CIRCLE 491 ON READER SERVICE CARD

The **PC4311**, an IEEE-488 interface for the PC and compatible machines, has been announced by **Applied Micro Technology, Inc.** The PC4311 is based on Texas Instruments TMS9914A and can perform as a talker, listener, or controller. The user can communicate with the GPIB under programmed I/O, interrupt, or DMA control. A software support package is supplied with the interface, featuring three levels of software: a menu-driven configuration, linkable assembly language subroutines, and an installable device driver. $420.
Applied Micro Technology, Inc., P.O. Box 3042, Tucson, AZ 85702; 602/622-8605

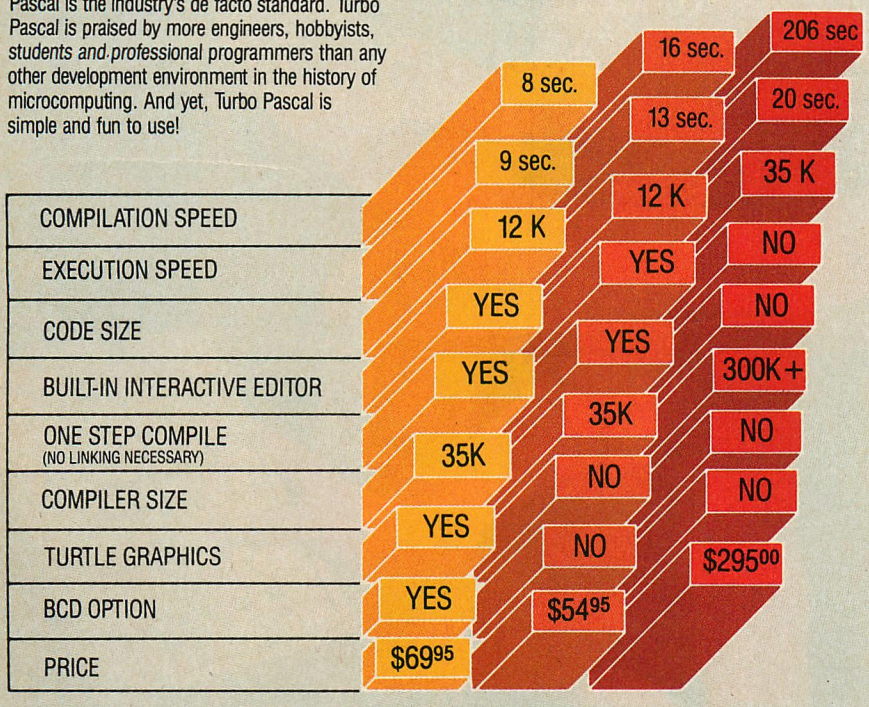
CIRCLE 486 ON READER SERVICE CARD

Intel Corporation has introduced a single-chip LAN controller for low-cost networks of personal computers used in office applications. The **82588 LAN controller** is a VLSI (very large-scale integration) device that supports emerging IEEE 802.3 standards for LANs such as the IBM PC Network and STARLAN (STARLAN is a low-cost network protocol being developed in conjunction with AT&T for implementation over installed telephone wiring). The controller is designed to meet a variety of networking needs. Its programmable data-link controller supports long and short topologies and various network framing, speed, and coding formats. For baseband applications, the 82588 supports the same end-of-carrier framing and Manchester encoding used in STARLAN networks. Network throughout is improved by the chip's use of collision-detection features rather than collision avoidance. The 82588 has a high-level command interface that reduces the processing load for the system's CPU; further, the chip supports buffer chaining to store received frames. Memory space is used efficiently because sort frames are not stored in long buffers designed to save large frames. The

They said it couldn't be done. Borland Did It. Turbo Pascal 3.0

The industry standard

With more than 250,000 users worldwide Turbo Pascal is the industry's de facto standard. Turbo Pascal is praised by more engineers, hobbyists, students and professional programmers than any other development environment in the history of microcomputing. And yet, Turbo Pascal is simple and fun to use!



The best just got better: Introducing Turbo Pascal 3.0

We just added a whole range of exciting new features to Turbo Pascal:

- First, the world's fastest Pascal compiler just got faster. Turbo Pascal 3.0 compiles twice as fast as Turbo Pascal 2.0! No kidding.
- Then, we totally rewrote the file I/O system, and we also now support I/O redirection.
- For the IBM PC versions, we've even added "turtle graphics" and full tree directory support.
- For all 16 Bit versions, we now offer two additional options: 8087 math coprocessor support for intensive calculations and Binary Coded Decimals (BCD) for business applications.
- And much much more.

The Critics' Choice.

Jeff Duntemann, PC Magazine: *"Language deal of the century . . . Turbo Pascal: It introduces a new programming environment and runs like magic."*

Dave Garland, Popular Computing: *"Most Pascal compilers barely fit on a disk, but Turbo Pascal packs an editor, compiler, linker, and run-time library into just 29K bytes of random-access memory."*

Jerry Pournelle, BYTE: *"What I think the computer industry is headed for: well documented, standard, plenty of good features, and a reasonable price."*

Portability

Turbo Pascal is available today for most computers running PC DOS, MS DOS, CP/M 80 or CP/M 86. A XENIX version of Turbo Pascal will soon be announced, and before the end of the year, Turbo Pascal will be running on most 68000 based microcomputers.

An Offer You Can't Refuse

Until June 1st, 1985, you can get Turbo Pascal 3.0 for only $69.95. Turbo Pascal 3.0, equipped with either the BCD or 8087 options, is available for an additional $39.95 or Turbo Pascal 3.0 with both options for only $124.95. As a matter of fact, if you own a 16 Bit computer and are serious about programming, you might as well get both options right away and save almost $25.

Update policy

As always, our first commitment is to our customers. You built Borland and we will always honor your support.

So, to make your upgrade to the exciting new version of Turbo Pascal 3.0 easy, we will accept your original Turbo Pascal *disk* (in a bend-proof container) for a trade-in credit of $39.95 and your Turbo87 original *disk* for $59.95. This trade-in credit may only be applied toward the purchase of Turbo Pascal 3.0 and its additional BCD and 8087 options (trade-in offer is only valid directly through Borland and until June 1st, 1985).

(*) Benchmark run on an IBM PC using MS Pascal version 3.2 and the DOS linker version 2.6. The 179 line program used is the "Gauss-Seidel" program out of Alan R. Miller's book: *Pascal programs for scientists and engineers* (Sybex, page 128) with a 3 dimensional non-singular matrix and a relaxation coefficient of 1.0.

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Pascal w/8087 & BCD $124.95 (SAVE $24.90) ____

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I Use: ___ PC-DOS ___ MS-DOS
___ CP/M 80 ___ CP/M 86

My computers' name/model is: ____

The disk size I use is:
☐ 5¼" ☐ 8" ☐ 3½"

For update: original Turbo disk must accompany order

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6

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CIRCLE NO. 115 ON READER SERVICE CARD


SIDEKICK
NOTES
* Bill - 303-742]
* Stocks
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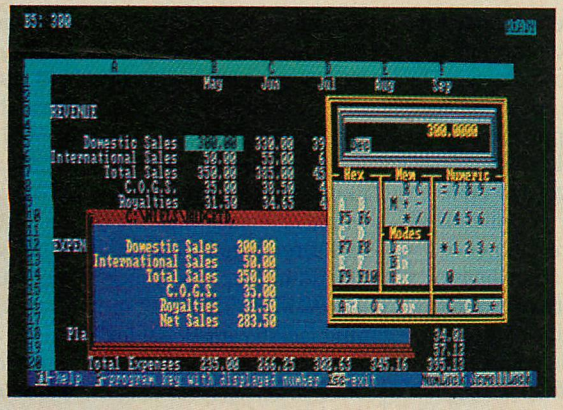
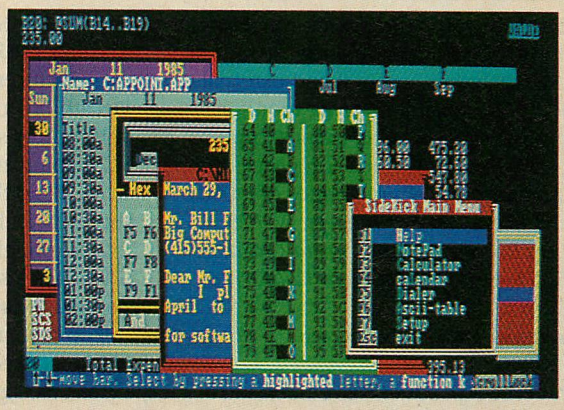
ASCII TABLE
IBM

Borland's SideKick Software Product of the Year

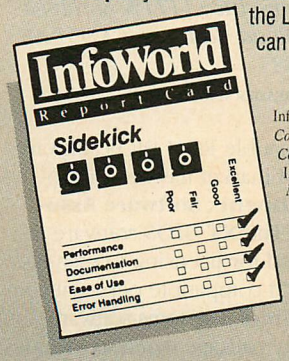
SideKick is InfoWorld Software Product of the Year. It won over Symphony. Over Framework. Over ALL the programs advertised in this magazine. Including, of course, all the "fly-by-night" SideKick imitations. SideKick . . . . Simply the best.



Here's **SideKick** running over Lotus 1-2-3. In the SideKick **Notepad** you'll notice data that's been imported directly from the Lotus screen. In the upper right you can see the **SideKick Calculator.**



All the **SideKick** windows stacked up over Lotus 1-2-3. From bottom to top: SideKick's **"Menu Window", ASCII table, Notepad, Calculator, Appointment Scheduler/Calendar,** and **Phone Dialer.** Whether you're running WordStar, Lotus, dBase, or any other program, SideKick puts all these desktop accessories instantly at your fingertips.



InfoWorld *Report Card 1984 by Popular Computing, Inc., a subsidiary of CW Communications Inc. Reprinted from* InfoWorld, *1060 Marsh Road, Menlo Park, CA 94025.*

Jerry Pournelle, BYTE: *"If you use a PC, get SideKick. You'll soon become dependent on it."*

Garry Ray, PC Week: *"SideKick deserves a place in every PC."*

Charles Petzold, PC Magazine: *"In a simple, beautiful implementation of WordStar's block copy commands, SideKick can transport all or any part of the display screen (even an area overlaid by the notepad display) to the notepad."*

Dan Robinson, InfoWorld: *"SideKick is a time-saving, frustration-saving bargain . . . ."*

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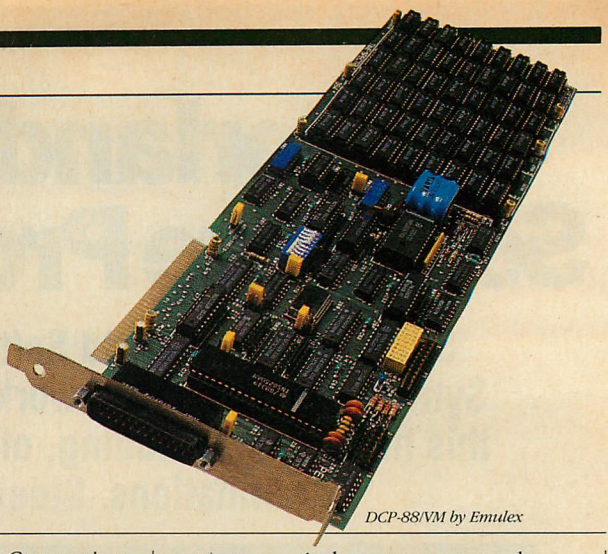
S6

Decathlon



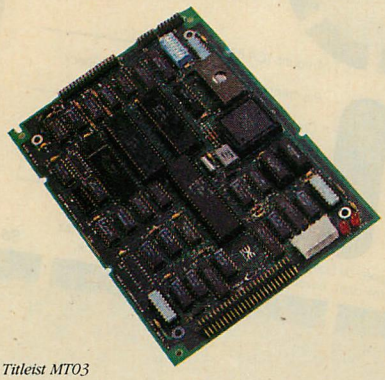
DCP-88/VM by Emulex

82588 also provides a wide range of network diagnostic and management functions, including internal and external loopbacks, channel activity monitoring, optional capture of all frames, capture of collided frames, and a register dump command. $45 (in quantities of 1,000). *Intel Corp., Literature Dept. W-175, 3065 Bowers Avenue, Santa Clara, CA 95051; 800/538-1876; in California, 800/672-1833*

CIRCLE 478 ON READER SERVICE CARD

Three new products have been introduced by **Emulex Corporation**. The **Persyst DCP-88/VM** (variable memory) distributed communications processor board, an expanded-memory version of the DCP-88, is a single-board, front-end processor for the PC, PC/XT, PC/AT, and compatibles. The DCP-88/VM can be used with a variety of software packages to emulate both SNA and Bisync 3270, 2780/3780, and HASP protocols. Based on the 8088 chip, the Persyst board can support up to four multiprotocol communications lines and a high-speed parallel printer port. $695.

The **Decathlon**, a compact, packaged subsystem, utilizes the SCSI (small computer systems interface) bus structure to provide high-capacity disk/tape storage for a wide range of CPUs. It interfaces to the DEC QBus and Unibus, the IEEE 796 Multibus, the PC, PC/XT, and compatible CPU bus structures through an Emulex-supplied SCSI host adapter. Connection to other CPUs can be made through a manufacturer-supplied host adapter. The Decathlon consists of the basic chassis with power supply, the appropriate SCSI-compatible disk and/or tape controller, and the user's choice of up to three 5¼-inch form-factor peripherals in either a single rack-mount cabinet or tower enclosure. Pricing according to configuration and memory capacity.



Titleist MT03

Emulex has also announced a new version of its **Titleist** tape controller series. Designated the Model **MT03**, the new version interfaces with the QIC-44 standard, which supports up to four Tandberg Data model 3309 one-quarter-inch streaming cartridge tape drives, with up to 60MB of archival storage per drive. Used in conjunction with an independent host adapter from Emulex, the MT03 interfaces through the SCSI to a variety of computers, including the PC, PC/XT, and PC/AT. It can be used with any system when the proper host adapter is made available. $435. *Emulex Corporation, 3545 Harbor Blvd., P.O. Box 6725, Costa Mesa, CA 92626; 714/662-5600*

CIRCLE 480 ON READER SERVICE CARD

SOFTWARE

Amber Systems has announced its first consumer product, which is called the **WindowMachine** program utility. Designed for the PC/XT, WindowMachine gives programmers the capability to build sophisticated windowing user interfaces for applications programs without displacing large segments of RAM. The WindowMachine was developed from the VSI Windows OEM program by Amber and is based on the concept of virtual screens: up to 255 windows can be displayed on one physical screen. These virtual screens may contain tables or text for midprogram reference or input/output windows to capture other information. Virtual screens can be up to 255 columns by 255 lines and reside in a dynamically allocated memory buffer. Unique features of WindowMachine include ZoomWindows that permit a virtual screen to grow or shrink from a single character cell, full control of virtual screen attributes, compatibility with all add-in graphics boards that emulate the PC-block character mode, a debugging facility, small system overhead of 15KB RAM for WindowMachine subroutines, and two-level documentation that includes on-line screen menus and support for speed reading. $59.95. *Amber Systems, Inc., 1171 S. Saratoga-Sunnyvale Road, San Jose, CA 95129; 408/997-1883*

CIRCLE 474 ON READER SERVICE CARD

PC/XT-compatible ROM BIOS software for the OEM market has been introduced by **Phoenix Software Associates Ltd.** The **XT BIOS** software is being offered for licensing to manufacturers of IBM-compatible personal computers as part of a systems-software compatibility package that also includes an XT DOS-compatible version of MS-DOS, a full range of utilities, and the GW BASIC language configured to resemble IBM's BASICA. Last May, the company introduced the industry's first original off-the-shelf PC ROM BIOS for OEMs designed not to infringe on IBM's ROM BIOS copyright, as part of its package for systems-software compatibility. Phoenix can also provide OEMs with any custom hardware or software engineering services required to install the compatibility software on an OEM's microcomputer. The company is offering unlimited use licensing of its entire PC/XT DOS-compatible systems-software package for $290,000. *Phoenix Software Associates Ltd., 1420 Providence Highway, Suite 101, Norwood, MA 02062; 617/769-7020*

CIRCLE 463 ON READER SERVICE CARD

Borland Does It Again: SuperKey $69.95

Sure, ProKey™ is a nice little program. But when the people who brought you Turbo Pascal and SideKick get serious about keyboard enhancers, you can expect the impossible . . . and we deliver.

	SuperKey	ProKey
ALL FEATURES RESIDENT IN RAM AT ALL TIMES	YES	NO
RESIDENT PULL-DOWN MACRO EDITOR	YES	NO
RESIDENT FILE ENCRYPTION	YES	NO
PROKEY COMPATIBILITY	YES	YES
DISPLAY PROTECTION	YES	NO
ABILITY TO IMPORT DATA FROM SCREEN	YES	NO
PULL-DOWN MENU USER INTERFACE	YES	NO
CONTEXT-SENSITIVE ON-LINE HELP SYSTEM	YES	NO
DISPLAY-ONLY MACRO CREATION	YES	NO
ENTRY AND FORMAT CONTROL IN DATA FIELDS	YES	NO
COMMAND KEYS REDEFINABLE "ON THE FLY"	69.95	NO
PRICE	69.95	129.95

Total ProKey compatibility. Every Prokey Macro file may be used by SuperKey *without change* so that you may capitalize on all the precious time you've invested.

Now your PC can keep a secret! SuperKey includes a resident file encryption system that uses your password to encrypt and decrypt files, even while running other programs. Two different encryption modes are offered:

1. Direct overwrite encryption (which leaves the file size unchanged) for complete protection. At no point is a second file that could be reconstructed by an intruder generated. Without your secret password, no one will ever be able to type out your confidential letters again!

2. COM or EXE file encryption which allows you to encrypt a binary file into an ASCII file, transmit it through a phone line as a text file and turn it back again into an executable file on the target machine (only of course if your correspondant knows the secret password!). Now, you will even be able to secretly exchange programs through Public Bulletin Board Systems or services such as CompuServe.

Totally memory resident at all times, gives SuperKey the ability to create, edit, save and even recall new or existing macro files anytime, even while running another program.

Pull down macro editor. Finally, a sensible way to create, edit, change and alter existing macro definitions. Even while using another application, a simple keystroke instantly opens a wordprocessor-like window where you're allowed to see, edit, delete, save and even attach names to an individual macro or file of macros, and much more.

Sorry ProKey !

Superb software at reasonable prices!
There is much more to SuperKey. Maybe the best reason to buy SuperKey is that it is a Borland International Product. Each one of our products is the best in its category. We only believe in absolutely superb software at reasonable prices!

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Whether you are a ProKey user or you've never used a keyboard enhancer before, your boat has come in: until June 1st 1985 you can get your copy of SuperKey at this special introductory price.

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SuperKey is available now for your IBM PC, XT, AT, jr. and truly compatible microcomputers.

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Credit Card Expir. Date: ____/____
Name on Card: _____
Card #: _____

Name: _____
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City: _____ Zip: _____
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K6

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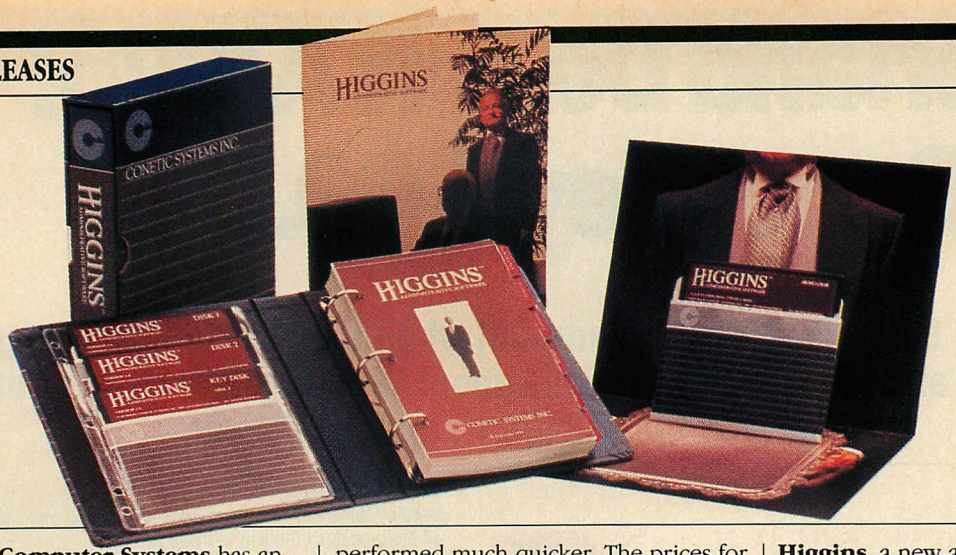

Heuristic Computer Systems has announced the **HCS/EDITOR.** HCS/E uses syntax, commands, and screen format similar to IBM's large-scale editor, SPF. However, only the syntax is fixed. A user may select any of the seven other data display formats and may use the HCSECUST program to change the main commands, line commands, scroll values, find parameters, function keys, and other control keys. In the end, a user may customize HCS/E so that it acts like, but does not look anything like SPF. HCS/E provides full diskette and machine failure recovery: the full diskette is removed and replaced by one with more space when the "DISK FULL" message is displayed. The auto save function occasionally makes a temporary copy of the file. If a machine failure should occur, the next time HCS/E is started it will recover the file and its changes to the last auto save and display the file at the proper spot. HCS/E is available on DOS, CP/M, and UNIX. $94.95.
Heuristic Computer Systems, 853 Hickory Drive, Carmel, IN 46032; 317/848-8981

CIRCLE 469 ON READER SERVICE CARD

HCS/EDITOR

New versions of **CADDRAFT** and **CADPLAN** for the PC/AT have been introduced by **Personal CAD Systems, Inc.** The programs are said to run 2½ to 4 times faster on the AT than on the XT, with every processing-intensive operation performed much quicker. The prices for the new software are about 15 percent higher than the same software for the XT. CADDRAFT is an entry-level drafting package. CADPLAN is a professional-level product that is used to create, edit, and plot designs for architectural renderings, floor plans, piping, wiring, and furniture placement. Capable of drawing up to 65 layers, CADPLAN is also well suited for mechanical design, drafting, and graphics-oriented documentation. CADDRAFT, $1495; CADPLAN, $1,600 (the database extraction option is $400 extra).
Personal CAD Systems, Inc., 981 University Avenue, Los Gatos, CA 95030; 408/354-7193

CIRCLE 464 ON READER SERVICE CARD

Pro/Tem Software has announced **Notebook II**, the second generation of its text-oriented database manager. Notebook II has a built-in text editor with word wrap, automatic reformatting, and instant screen update. It also is able to read in files from word processors, public-access databases, and other database managers. Notebook II can accept control and extended characters. Field and record sizes are not predefined, but automatically expand as text is entered; up to 50 fields are permitted. Notebook II includes full sort and selection functions. It can select, based on any text embedded in any field, without the need for key words. It also includes a function that can increase entry and retrieval speed by listing words entered in a key field. New commands and menus hasten movement among records and fields and will display a help system menu for the relevant part of the program when signaled. New utilities include the ability to merge and clone databases. Notebook II works with all IBM computers that run PC-DOS. $189.
Pro/Tem Software, 2363 Boulevard Circle, Walnut Creek, CA 94595; 800/826-2222 or 415/947-1000

CIRCLE 472 ON READER SERVICE CARD

Higgins, a new administrative assistant software product, has been released by **Conetic Systems, Inc.** Built on a sophisticated database, Higgins allows complete interaction of all administrative tasks, taking care of such tasks as time management, personal filing, expense reporting, telephone directories, autodialing and routing, project task lists, calculations, reminders, and so on. Higgins is being produced in both a single-user version that can maintain up to seven different users' data and a LAN version that will be sold primarily through VARs and OEMs. Higgins is interactive with other DOS-based programs on the PC/XT or PC/AT and supports macros for further personalization. Prices: single-user version, $395; pricing on the LAN version is dependent upon the number of users on the LAN.
Conetic Systems, Inc., 1470 Doolittle Drive, San Leandro, CA 94577; 415/633-0291

CIRCLE 473 ON READER SERVICE CARD

Applied i has announced the release of a new version of TUTSIM, the dynamic simulation program for modeling continuous systems on a microcomputer. **TUTSIM version 3.0**, for use on the PC, PC/XT, PC/AT, and PC*jr*, offers many new program features plus a new manual to use with this engineering program. Among the program's new features are a new data file output, a new data file input, new logic blocks, a new history block, a new control block, and new commands, along with support for the 8087 coprocessor, the Hercules high-resolution graphics board, an additional printer/plotter, and the IBM short form expanded to 15 blocks. Full professional version with license, $475.00 to $495.00 (allows 999 blocks per model); short form with full manual, $29.95 (allows 7 to 15 blocks per model).
Applied i, 200 California Avenue, #214, Palo Alto, CA 94306; 415/325-4800

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Speed, Power, Price.
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The industry standard. With more than 250,000 users worldwide Turbo Pascal is the industry's de facto standard. Turbo Pascal is praised by more engineers, hobbyists, students and professional programmers than any other development environment in the history of microcomputing. And yet, Turbo Pascal is simple and fun to use!

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Jeff Duntemann, PC Magazine: *"Language deal of the century . . . Turbo Pascal: It introduces a new programming environment and runs like magic."*

Dave Garland, Popular Computing: *"Most Pascal compilers barely fit on a disk, but Turbo Pascal packs an editor, compiler, linker, and run-time library into just 29K bytes of random-access memory."*

Jerry Pournelle, BYTE: *"What I think the computer industry is headed for: well documented, standard, plenty of good features, and a reasonable price."*

Portability. Turbo Pascal is available today for most computers running PC DOS, MS DOS, CP/M 80 or CP/M 86. A XENIX verison of Turbo Pascal will soon be announced, and before the end of the year, Turbo Pascal will be running on most 68000 based microcomputers.

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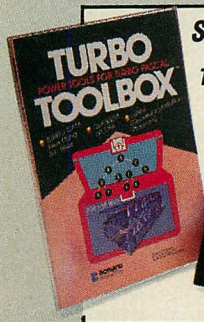

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The perfect complement to Turbo Pascal. It contains: ***Turbo-Access***, a powerful implementation of the state-of-the-art B+tree ISAM technique; ***Turbo-Sort***, a super efficient implementation of the fastest data sorting algorithm, "Quicksort on disk". And much more.

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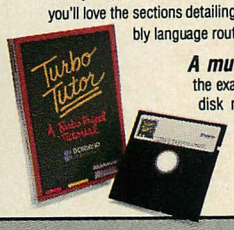

A must. You'll find the source code for all the examples in the book on the accompanying disk ready to compile. Turbo Tutor might be the only reference on Pascal and programming you'll ever need.

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(The 87 Software pak is only $120. when purchased with either the 287 FAST/5 or the 87 Chip!)

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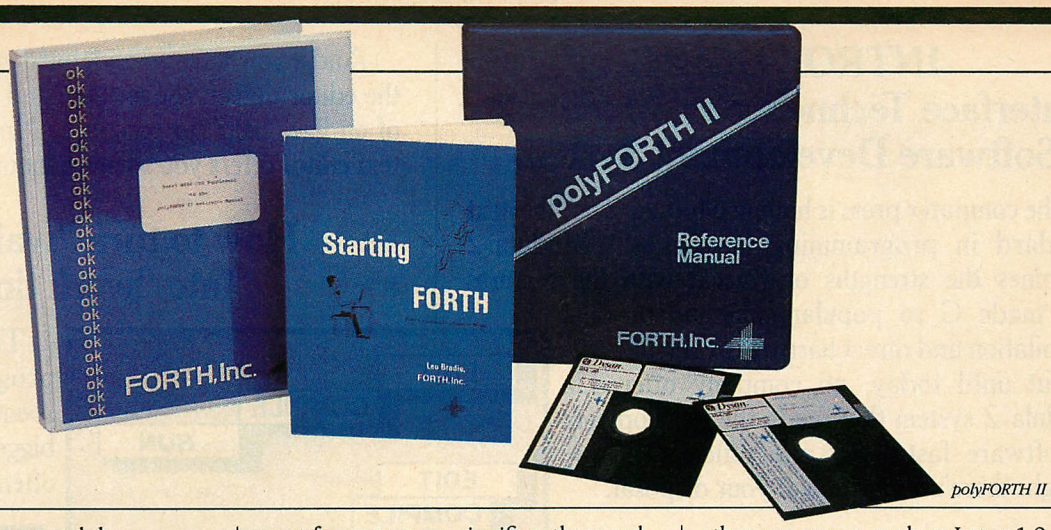


polyFORTH II

FORTH, Inc. has announced the availability of **polyFORTH II,** its multitasking, multiuser operating system, for microcomputers running MS-DOS. According to the company, polyFORTH II supports more users at a higher speed on a CPU than any other system. In contrast to other operating systems offered for the 8086/88-based computers, polyFORTH II is also designed to support any number of asynchronous processes running concurrently. Tasks may have private partitions or may execute shared, reentrant routines. Specially coded to take advantage of standard BIOS and BDOS calls for disk and terminal I/O, the new polyFORTH offers MS-DOS users an ability to run multiple terminals, unlimited control tasks, and concurrent printer operation. The polyFORTH MS-DOS version may be purchased in several levels reflecting increasing software capability and support services. Level 3, priced at $600, includes the operating system, FORTH Turnkey Compiler, assembler, editor, math library, database support system, utilities, and source for everything but the nucleus. Level 4, at $3,200, includes all features of Level 3 plus full system source and the Target Compiler, capable of generating ROMable applications or recompiling polyFORTH itself. Levels 5 and 6 feature extended support services.
FORTH, Inc., 2309 Pacific Coast Highway, Hermosa Beach, CA 90254; 213/372-8493
CIRCLE 468 ON READER SERVICE CARD

A new release of the **Microsoft Macro Assembler** that supports the entire Intel family of 16-bit microprocessors has been announced by **Microsoft Corporation**. The assembler is accompanied by an extensive set of development utilities, including a symbolic debug utility that allows programmers to examine and step through their source code as well as their object code. This utility provides a controlled testing environment for programs, significantly speeding development time. One of the main differences between the new Microsoft Macro Assember release and the previous version is that the new release supports a broader variety of processors. In addition to the 8086/88 environment supported by the previous release, the new version also includes 80286 and 80186 opcodes and pseudo ops, allowing programmers to write applications that run on the full Intel 80 series of microprocessors. Programs written with the new Macro Assembler will run on the PC/AT; it includes switches to select case sensitivity. Minimum system requirements are 128KB of RAM, one disk drive, and MS-DOS 2.0 or higher. Price: $150; an upgrade can be obtained at a nominal fee by writing the Microsoft Customer Service Department.
Microsoft Corporation, 10700 Northup Way, Box 97200, Bellevue, WA 98009; 800/426-9400 or 206/828-8080
CIRCLE 466 ON READER SERVICE CARD

LCS/Telegraphics has announced the release of **TelePaint**, a mouse-driven, color graphics screen painting package. The software runs on the PC, PC/XT, PC/AT, PC*jr,* and compatibles. TelePaint

Microsoft Macro Assembler

provides graphics screen painting that utilizes an interface with pull-down menus and pop-up dialogue windows. It allows the user to create full 8½-by-11-inch pages, combining color graphics and text. The user can capture and enhance graphs and charts created by other programs, such as Lotus 1-2-3. With either a color or black-and-white printer, the user can create professional-looking documents and high-quality, full-page overhead transparencies. TelePaint requires 192KB of memory, an IBM display adapter, and operates with mice from Summagraphics, Microsoft, and Mouse Systems. $149.
LCS/Telegraphics, 261 Vassar Street, Cambridge, MA 02139; 617/547-4738
CIRCLE 456 ON READER SERVICE CARD

JMI Software Consultants, Inc. has announced **release 1.6 of BASTOC**, its software tool that provides extensive BASIC facilities on UNIX and other systems supporting C compilers. The new release supports the TRS-XENIX MBASIC Interpreter dialect, complementing the currently supported Microsoft Disk BASIC and Digital Research CBASIC versions of BASTOC. BASTOC translates programs written in BASIC to formatted C source code. It can be used as a conversion tool and can serve as a conventional BASIC compiler when configured as a preprocessor to a C compiler. BASTOC may be tailored to address local variations in BASIC. One new feature is a BASIC compiler program that uses the host system's C compiler and linker. It is appropriate for OEMs configuring systems that include a C compiler, but not BASIC. $350.
JMI Software Consultants, Inc., 904 Sheble Lane, P.O. Box 481, Spring House, PA 19477; 215/628-0846
CIRCLE 460 ON READER SERVICE CARD

Correction: An item in the Tech Releases section of the January 1985 issue (p. 192) incorrectly stated that Tym/VSAM, a program recently released by InfoTym, provides critical VSAM support for PC/XT users. It should have said that it provides support for PC/XT-370 users.
InfoTym, Tym/VSAM Marketing, 20705 Valley Green Drive, Cupertino, CA 95014; 800/325-1551

INTRODUCING
Interface Technologies' Modula-2 Software Development System

The computer press is hailing Modula-2 as "the next standard in programming languages." Modula-2 combines the strengths of Pascal with the features that made C so popular, like independent compilation and direct hardware control.

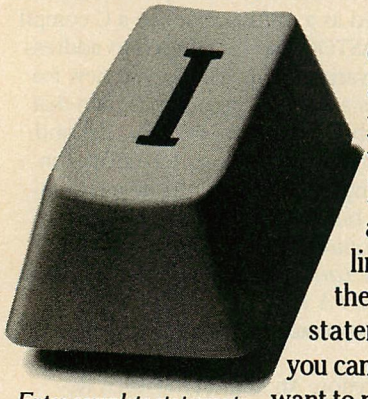
But until today, no company offered a Modula-2 system that made the development of software fast, easy and efficient. Now, though, there's a new tool at your disposal.

The fast, powerful tool for programmers

The breakthrough is here: Interface Technologies' new Modula-2 Software Development System for the IBM® PC, XT, AT and compatible computers to give programmers the same quantum leap in productivity spreadsheets and word processors gave to end-users. It can reduce monotonous wait time, will dramatically increase speed, help stop thoughtless mistakes, and free you to become more creative in virtually all of your programming efforts.

How to speed input and eliminate 30% of errors

Thirty percent of programming mistakes are syntax errors and simple typos in the program structure. Our "syntax-directed" Modula-2 editor does away with these time-consuming headaches once and for all.



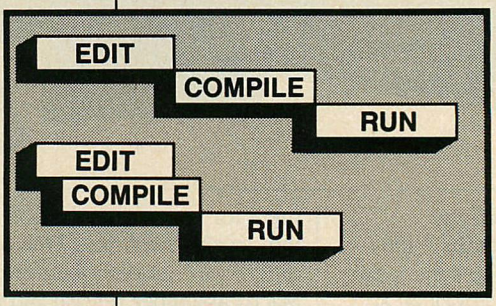
Enter complete statements with one keystroke.

It speeds input by cutting manual typing as much as 90%, letting you enter statements with a single keystroke. For example, if you type a capital "I" to begin a line, the editor completes the logical "IF THEN" statement automatically, so you can concentrate on what you want to program, rather than concentrate on what you're typing.

The editor locks out errors, finishing statements and procedures in perfect accord with the standardized rules of Modula-2. It also indents and formats your text automatically, making programs easy to read and maintain, an important feature on big projects.

And if you leave an undefined variable or data type, the editor detects the mistake and gives you the option of on-line "help" to correct it. No other programming text editor offers you so much innovation at any price.

How to turn "wait time" into "work time"



It not only has a faster compiler, it also saves time by compiling while you edit.

The vast majority of programming time is spent waiting, and the biggest slowdown is most often with compilers.

THE ANATOMY OF A

Our compiler turns wait time to work time with a new innovation that lets you compile in the "background."

With background compilation, your program is automatically compiled into object code line by line as you work, every minute you spend writing or editing a Modula-2 program!

When you're finished editing, all that's left for the compiler is a quick mopping up job that generates optimized native code in a single pass.

How quick is "quick"?

Thanks to background compilation and the fact that the compiler itself is so fast, Interface Technologies' compiler turns 100 lines of typical Modula-2 text into optimized machine code in *under five seconds.*

Plus the Interface compiler produces compact code with execution speed superior to that produced by any other Modula-2 compiler on the market.

How to do two things at once

Along with the background compiler and syntax-directed editor, which can save you hours every day and make you more productive, Interface Technologies' Software Development System gives your monitor

windows so you can refer to one file while you edit another simultaneously, saving you even more time.

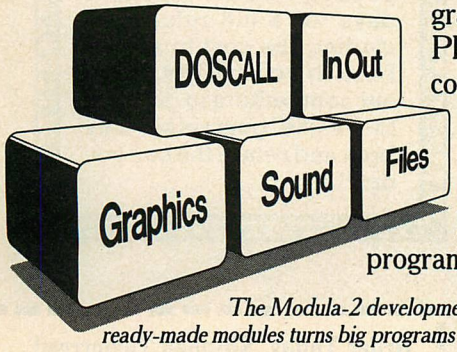
Concurrent editing of two or more files is especially useful when doing programming work that's intended for separate compilation, and Interface Technologies has the only Modula-2 system on the market that provides you with this helpful benefit for developing software.

Work with multiple files faster, easier in windows.

How preprogrammed modules speed development

One of the advantages of Modula-2 is that it lets you build large, reliable programs quickly, by linking together many smaller "building-block" modules.

The development system's toolkit of precompiled program modules includes the standard Modula-2 library, and adds exclusive link-and-run modules for direct calls to the operating system, sound, and color graphics support. Plus you get low-cost updates from the Interface Technologies fast-growing library of new programming modules.



The Modula-2 development system's toolkit of ready-made modules turns big programs into smaller projects.

Increase productivity for $249

Interface Technologies' Software Development System is fast, powerful and unlimited. It works so well that it's the same tool Interface Technologies is using to write business and consumer applications in Modula-2.

For $249, you get the syntax-directed editor and compiler, linker, module library and tutorial that will have even modestly experienced programmers writing in Modula-2 in days. And you have full rights to your work; there's no license fee for programs you develop with the Interface Technologies system.

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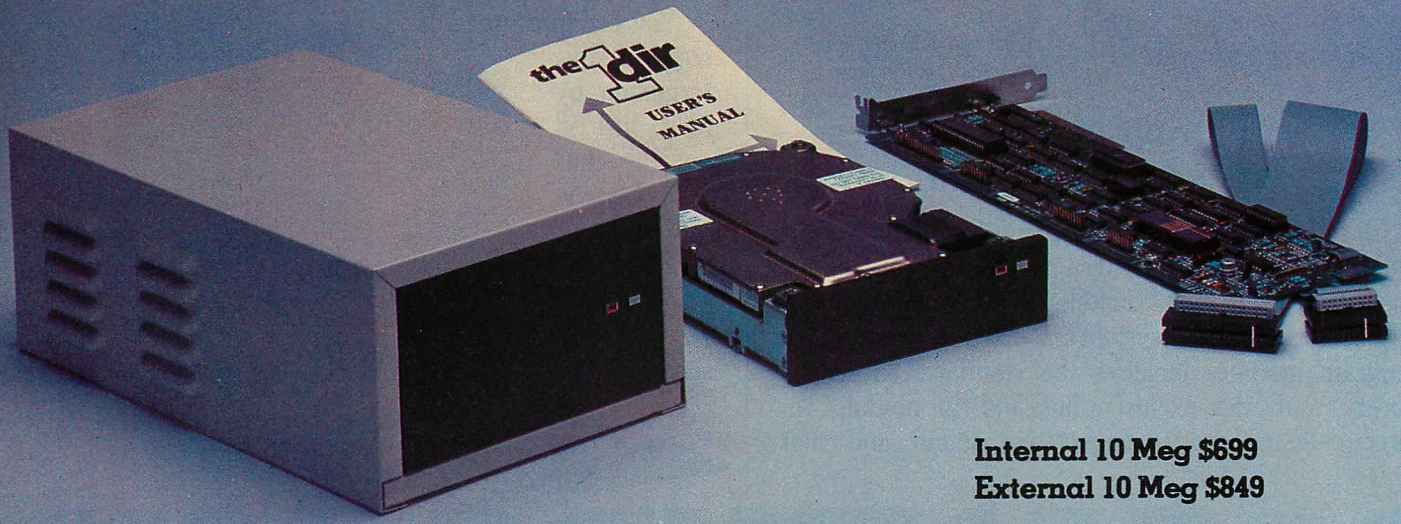
The Hard Disk With The Software Shell



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Using the same amount of power as a floppy drive, the Qubie' hard disk uses less energy than other aftermarket drives.

The drives come complete with 1dir software. 1dir's commands are in English, eliminating the need to type in DOS commands, and are all selected by using cursor control keys. 1dir even explains commands with HELP screens that give you on-line advice when you need it.

Qubie' drives are made of special plated recording media. They withstand the vibration and movement that has damaged hard disks in the past. In fact, Qubie' drives have been selected by several computer makers for use in their portable computers.

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TED MIRECKI

Replacing RENAME

An assembly language program allows the user to rename subdirectories and volume labels, as well as files.

One frustrating inconvenience of DOS 2.x is that it does not allow the renaming of subdirectories and volume labels. The RENAME (alias REN) command does not work on subdirectories or labels, so once a subdirectory or volume has been created with a particular name, the only way to change that name is to copy all files into a new directory or onto a new disk with the desired name. This process can take a long time and it is certainly impractical for changing a hard disk volume label.

Most DOS keyboard commands are also available as INT 21H function calls from assembly language programs; two such function calls are offered for renaming. Function 56H operates much as the RENAME command: it handles path names, but will rename only normal files, not subdirectories or volume labels. (This function differs from RENAME in that it accepts two different path names and can move a file between directories without copying the file contents.)

Function 17H accepts only file names, not path names, because it accesses files by means of an FCB (File Control Block). It will rename directories and labels as well as normal files, however, if it is provided with an extended FCB containing the appropriate attribute value: 10H for subdirectories, 08H for labels, and 18H for both of these.

SUPEREN (see the listing) uses function 17H to provide a "super-rename" feature that will change the name of any file, subdirectory, or volume label. The name to be changed must match the program's first command-line parameter, and the new name will be built up from the second parameter. If either parameter is a volume label longer than eight characters, a period must be inserted after the eighth character.

Wild-card characters can be used in both original and new names, as long as the guidelines documented under function 17H in the DOS manuals are followed. To limit the processing to either subdirectories or volume labels, the value at the symbol 'ATTR' should be changed to 10H (subdirectories) or 08H (volume labels)—it might be useful to have two versions of the program. It is important to note, however, that *any* version of the program may also be used to rename normal files that match the first parameter.

SUPEREN can be implemented by entering it into an editor or word processor, assembling it, linking it, and converting it to a .COM file with EXE2BIN; the .EXE version should not be run. The command

EXE2BIN SUPEREN SUPEREN.COM

can be used to create a .COM file directly from the .EXE version, without going through a .BIN phase.

Ted Mirecki has a master's degree in computer science and 20 years of experience in information processing.

LISTING: SUPEREN.ASM

```
        PAGE
        PAGE    72,120
TITLE   SUPEREN   Change name of file, sub-dir or vol ID.
COMMENT "       SUPEREN   [d:]name1    name2
        Renames files or subdirectories from name 1 to name2.
        Name1 & name2 may have extensions and wild characters.
        Action of the program is as described in the DOS manual
        for INT 21, function 17.
"
COM     SEGMENT
        ASSUME CS:COM, DS:COM, ES:COM, SS:COM
        ORG     5CH     ;FCB FORMED FROM NAME1
FCB1    LABEL   BYTE
DRIVE1  DB      ?
NAME1   DB      11 DUP(?)
        ORG     6CH     ;FCB FORMED FROM NAME2
FCB2    LABEL   BYTE
DRIVE2  DB      ?
NAME2   DB      11 DUP(?)
        ORG     100H
SUPEREN PROC
        MOV     DX,OFFSET INVDR$        ;POINT TO ERROR MESSAGE
        TEST    AL,AL           ;TEST FOR VALID DRIVE1 ID
        JNZ     ERROR
        MOV     DX,OFFSET INVPAR$
        CMP     NAME1,' '               ;CHECK IF NAME1 IS THERE
        JE      ERROR
        CMP     NAME2,' '               ;CHECK FOR NAME 2
        JE      ERROR
        MOV     SI,OFFSET FCB1          ;POINT TO NAME1 FCB
        MOV     DI,OFFSET OLDN          ;POINT TO OLD NAME FIELD
        MOV     CX,12           ;MOVE 12 BYTES
        REP     MOVSB           ;MOVE NAME1 TO EXTENDED FCB
        MOV     SI,OFFSET NAME2 ;POINT TO NAME2, NOT DRIVE
        MOV     DI,OFFSET OLDN+11H      ;POINT TO NEW NAME FIELD
        MOV     CX,11           ;NAME EX DRIVE = 11 BYTES
        REP     MOVSB           ;MOVE NAME2 TO EXTENDED FCB
        MOV     DX,OFFSET XFCB          ;POINT DX TO EXTENDED FCB
        MOV     AH,17H          ;FUNCTION 17 = RENAME
        INT     21H
        TEST    AL,AL           ;TEST FOR ERRORS
        JZ      EXIT            ;NO ERRORS IF AL = 0
        MOV     DX,OFFSET INVNAM$       ;ELSE POINT TO ERROR MSG
ERROR:  MOV     AH,9            ;DISPLAY ERROR MESSAGE
        INT     21H
EXIT:   INT     20H             ;RETURN TO DOS
SUPEREN ENDP
INVDR$  DB      0DH,0AH,'Invalid drive id$',0DH,0AH,'$'
INVPAR$ DB      0DH,0AH,'2 params needed:[d:]oldname, newname'
        DB      0DH,0AH,'$'
INVNAM$ DB      0DH,0AH,'Name not found or already exists'
        DB      0DH,0AH,'$'
XFCB    DB      0FFH    ;EXTENDED FCB ID BYTE
        DB      5 DUP(0)
ATTR    DB      18H     ;ATTR FOR SUB-DIRS & VOL LABELS
OLDN    DB      37 DUP(0)       ;OLD & NEW NAMES GO HERE
COM     ENDS
        END     SUPEREN
```

TED FORGERON

We Interrupt this Program

The default Ctrl-Break interrupt handler can be replaced with customized routines.

IBM recommends that programs be designed to "interrupt the current process" whenever a Ctrl-Break is detected. Pressing Ctrl-Break will abort most PC-DOS commands; it is the special handling of Ctrl-Break by the BIOS and DOS that allows these programs to be interrupted.

Both PC-DOS and the ROM BIOS treat Ctrl-Break as a special key. The BIOS sets a flag whenever its low-level keyboard handler detects that Ctrl-Break has been pressed. When DOS notices that the flag has been set, it executes a software interrupt to invoke the system default Ctrl-Break interrupt handler. The default Ctrl-Break interrupt handler can easily be replaced with a customized version, so that this same Ctrl-Break detecting capability can be incorporated into an applications program. An interrupt handler is nothing more than a subroutine that gets control when a particular interrupt is executed. In this case, DOS executes a software interrupt 23H when it detects that Ctrl-Break has been pressed.

The listing below, BREAK.ASM, shows four routines that can be used for setting up and detecting Ctrl-Break. All four can be called from Pascal, C, or assembly language programs.

INSTALL is responsible for placing the address of the new Ctrl-Break interrupt handler into the correct spot in the interrupt-vector table. Interrupt vectors are used so that DOS can find the Ctrl-Break interrupt handler without having to know its address in advance. A call to INSTALL should be placed near the beginning of programs that will use this Ctrl-Break detecting routine.

BREAK_HANDLER is the actual Ctrl-Break interrupt handler. As the listing shows, this routine simply sets a flag to signify that Ctrl-Break has been pressed. Applications programs do not need to call BREAK_HANDLER; it is called automatically when DOS executes INT 23H.

CHECK_BREAK is a boolean function that can be called in order to see if Ctrl-Break has been pressed.

REMOVE puts the address for the original DOS Ctrl-Break handler back in the interrupt vector. Applications programs should call REMOVE just before exiting.

Ted Forgeron is vice-president of systems software engineering at Multisoft Corporation in Beaverton, Oregon.

LISTING: BREAK.ASM

```
        TITLE   BREAK -- Break Handling Utilities Module

TRUE            EQU     01H             ; boolean true
FALSE           EQU     00H             ; boolean false
BREAKINT        EQU     23H             ; dos control-break intrpt
GETVECTOR       EQU     35H             ; dos get vector function
SETVECTOR       EQU     25H             ; dos set vector function
DOS_FUNCTION    EQU     21H             ; dos function call

BREAK SEGMENT PUBLIC 'CODE'
BREAKFLAG       DB      0               ; break key hit flag
SAVEBREAK       DD      0               ; saved break vec. contents
        ASSUME  CS:BREAK
        ASSUME  DS:NOTHING

; CHECK_BREAK checks if ctrl-break has been pressed.  It returns
; true if ctrl-break has been pressed and false if it hasn't.

        PUBLIC  CHECK_BREAK
CHECK_BREAK     PROC FAR
        XOR     AX,AX                   ; clear ax
        MOV     AL, BREAKFLAG           ; return value = breakflag
        MOV     BREAKFLAG, FALSE        ; reset break flag
        RET
CHECK_BREAK     ENDP

; INSTALL_BREAK_HANDLER sets up a ctrl-break interrupt handler. It
; also saves the address of the former break handler so that it can
; be restored later.

        PUBLIC  INSTALL_BREAK_HANDLER
INSTALL_BREAK_HANDLER PROC FAR
        PUSH    DS
        MOV     AL,BREAKINT             ; AL = break interrupt
        MOV     AH,GETVECTOR            ; AH = dos function code
        INT     DOS_FUNCTION            ; call dos
        MOV     WORD PTR SAVEBREAK,BX   ; save offset in int vector
        MOV     WORD PTR SAVEBREAK+2,ES ; save base in int vector
        MOV     AL,BREAKINT             ; AL = break interrupt
        MOV     AH,SETVECTOR            ; AH = dos function code
        MOV     DX,OFFSET BREAK_HANDLER ; DX = offset of brk hdlr
        MOV     BX,CS                   ; BX = this segment
        MOV     DS,BX                   ; DS = this segment
        INT     DOS_FUNCTION            ; call dos
        POP     DS
        RET
INSTALL_BREAK_HANDLER  ENDP

; BREAK HANDLER is invoked by the bios when ctrl_break is pressed.

BREAK_HANDLER   PROC FAR
        MOV     BREAKFLAG, TRUE         ; breakflag = yes, break hit
        IRET
BREAK_HANDLER   ENDP


; REMOVE BREAK HANDLER restores the previous ctrl-break handler.

        PUBLIC  REMOVE_BREAK_HANDLER
REMOVE_BREAK_HANDLER PROC FAR
        PUSH    DS
        MOV     AL,BREAKINT             ; AL = break interrupt
        MOV     AH,SETVECTOR            ; AH = dos function code
        MOV     DX,WORD PTR SAVEBREAK   ; DX = saved 1st word
        MOV     BX,WORD PTR SAVEBREAK+2 ; BX = saved 2nd word
        MOV     DS,BX                   ; DS = saved 2nd word
        INT     DOS_FUNCTION            ; call dos
        POP     DS
        RET
REMOVE_BREAK_HANDLER ENDP
BREAK   ENDS
        END
```

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J. EDWARD VOLKSTORF, JR.

The Blinking Cursor

BASIC's block cursor in a graphics mode can be changed to a blinking cursor.

It is standard practice for good BASIC programs to use individual character input instead of INPUT or LINE INPUT in both text and graphics modes. Such programs use INKEY$ to filter out unwanted characters, restrict data to a fixed area on the screen, and so on. Unfortunately, graphics mode lacks the blinking cursor that most users have come to associate with the current data-entry position. Instead, a simple block character sits at the next character position.

The program in the listing below contains a subroutine (beginning at line 2000) that is designed for character-mode input in any of the graphics modes on the IBM PC. Basically, the subroutine traps individual characters via the INKEY$ statement. In addition, after some number of INKEY$ checks the character at the current cursor position is replaced by a user-defined character.

Before the subroutine is called, it must be initialized by defining the character codes used for keyboard input. The initialization routine begins at line 1000 in the listing. Note that the extended two-byte characters are coded and processed numerically as values greater than 256—that is, 256 plus the ASCII code of the second character in the two-character sequence. The character to be used as the cursor is defined in line 1100. A standard repertoire of editing keys is supported: cursor left/right, Ins, Del, BS, and Esc (the latter erases the current field to blanks). Input to a particular field is considered complete when the Enter key is pressed.

For individual calls to the subroutine, ROW and COL are set to the screen row and column where input is to take place. The variable FL defines the field length being entered, and A$ is the actual value returned. The variable A$ must be predefined to the length FL with blanks; alternatively, some other initial default value could be used. If another initial default value is used, the subroutine allows the default value to be edited. Be sure that this field is displayed before the subroutine is called, so that the user can see it.

Within the subroutine, the variable KS$ takes on the value of either the cursor or the character at the current input position. KS$ alternates between these two values after every eight calls to INKEY$. The code for the blink rate begins at line 2030 in the listing. In interpreted BASIC, the blink rate is approximately the same as the character-mode cursor. If the subroutine is compiled, the number of calls between each alternation should be increased somewhat in order to compensate for the more rapid execution time.

J. Edward Volkstorf is a freelance writer and consultant in educational computing. He is the author of Graphics Programming on the IBM Personal Computer.

LISTING: ART3.BAS

```
0  ' Graphics mode keyboard processor
10 ' J. Edward Volksdorf, Jr. -- author
12 '
15 '
20 SCREEN 1 : CLS : PRINT "KPROC example..." : PRINT
30 GOSUB 1030 ' initialize subroutine's special keys
40 ROW=9 : COL=10 : FL=8 : A$=SPACE$(FL)  ' set values for call
50 GOSUB 2030 ' call the subroutine
55 '
60 LOCATE 3,1 : PRINT "Read> ",A$
70 END
1000 '
1010 ' define constants for keyboard processor
1020 '
1030 K1=13  ' Enter - exit entry
1040 K2=8   ' BackSpace - cursor left and delete
1050 K3=27  ' Esc - blank field
1060 K4=331 ' move cursor to left
1070 K5=333 ' move cursor to right
1080 K6=338 ' Ins - insert a space
1090 K7=339 ' Del - delete character
1100 K8=95  ' ASCII cursor char code
1105 '
1110 RETURN
2000 '
2010 '  keyboard processor
2020 '
2030 KC=0 : KP=1  '  blink count, char pointer
2040 KC=(KC+1) MOD 16:KS$=MID$(A$,KP,1)  ' blink a field char
2050 IF KC>7 THEN KS$=CHR$(K8)            '   or the "cursor"
2055 '
2060 LOCATE ROW,COL+KP-1:PRINT KS$;       ' blink it
2070 K$=INKEY$ : IF K$="" THEN 2040       ' keystroke made?
2075 '
2080 LOCATE ROW,COL+KP-1
2085 PRINT MID$(A$,KP,1);          ' yes, clear blink
2086 '
2087 ' convert to number
2088 '
2090 KS=ASC(K$) : IF KS=0 THEN KS=256+ASC(RIGHT$(K$,1))
2100 IF KS>31 AND KS<256 THEN 2250       ' bypass some
2110 '
2120 ' check for editing char's
2130 '
2140 IF KS=K1 THEN RETURN
2150 IF KS=K2 AND KP>1 THEN KS$=MID$(A$,KP,FL-KP+1)+" "
:A$=MID$(A$,1,KP-2)+KS$:KP=KP-1:GOTO 2060
2160 IF KS=K3 THEN A$=SPACE$(FL):LOCATE ROW,COL
:PRINT A$;:GOTO 2030
2170 IF KS=K4 THEN KP=KP+(KP>1):GOTO 2040
2180 IF KS=K5 THEN KP=KP-(KP<FL):GOTO 2040
2190 IF KS=K6 THEN KS$=" "+MID$(A$,KP,FL-KP)
:A$=MID$(A$,1,KP-1)+KS$:GOTO 2060
2200 IF KS=K7 THEN KS$=MID$(A$,KP+1,FL-KP)+" "
:A$=MID$(A$,1,KP-1)+KS$:GOTO 2060
2205 '
2210 BEEP : GOTO 2040 ' invalid edit char
2220 '
2230 ' save a char, display it and continue
224 '
2250 MID$(A$,KP,1)=K$ : LOCATE ROW,COL+KP-1 : PRINT K$;
2260 KP=KP-(KP<FL) : GOTO 2040
```

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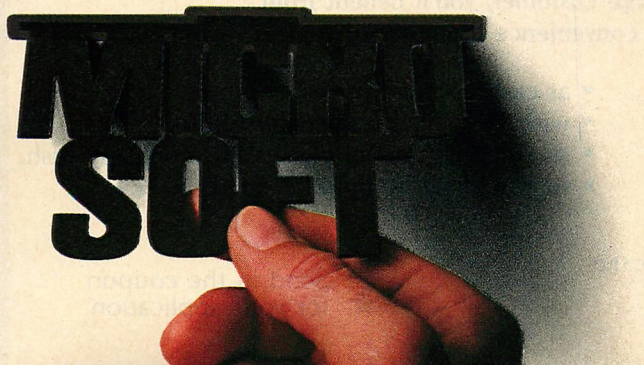

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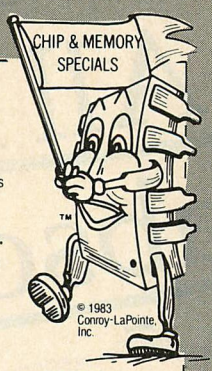

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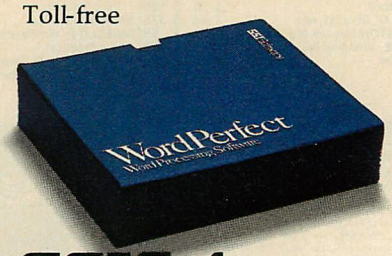

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Uptown Printers

IBM's Quietwriter and Wheelprinter offer new technology, flexibility, and quiet to the high-end printer market.

RICHARD M. FOARD

PHOTOGRAPHS • MARC DAVID COHEN

IBM has introduced two new letter-quality printers for the Personal Computer family: the Quietwriter (5201) and the Wheelprinter (5216). Developed and manufactured by IBM's Information Systems Group, the two printers are byproducts of the firm's broadest application of new technology to the office typewriter marketplace since the introduction of Selectric typewriters, over two decades ago.

IBM has capitalized thoroughly on the opportunity for modular design and packaging presented by the large amount of function that is common to printers and typewriters. Along with the new printers, IBM has added three typewriters to its lineup: the Quietwriter 7, which shares an innovative thermal transfer print mechanism with the Quietwriter printer; and two models of Wheelwriter typewriters, which, along with the Wheelprinter, are based on a brand new tooling of the familiar daisy-wheel technology.

As suggested by its name, the Quietwriter is distinguished by its lack of noise. Printing in the left-to-right direction only, the print head assembly moves smoothly across the page with a discreet, rhythmic sound that bears no resemblance whatsoever to the normally raucous whine of impact, dot-matrix

printers. The only sound discernible from a Quietwriter at work is the low whir of the print head making its idle carriage return movement. IBM's noise level rating is 53 dBA.

Thermal transfer is not a new printing technology, but the Quietwriter's thermal print mechanism has an innovative twist. IBM has developed a multilayer *resistance ribbon* that responds to electrical currents applied from the 40 vertically stacked pins in the print head by internally developing heat and fusing the character image to the paper without striking it. These characters are crisp, clean, and, with the naked eye, very hard to distinguish from fully formed characters (imagine the resolution attainable with an array of 40 dots, compared to that achieved on the IBM Monochrome Display using 14 vertical dots). A three-position contrast control switch sets the boldness of printed text, which is dark and well-defined even at the lowest contrast setting.

The special ribbon is encased in a bulky, although easily replaceable, cartridge and is advertised to provide about 160,000 character impressions (about 64 single-spaced pages). Replacement ribbons cost $12.00.

A print head cleaning ribbon is supplied with the Quietwriter as standard equipment; IBM recommends that the print head be cleaned whenever a decline in print quality is noticed. Replacement cleaning ribbons are available for $5.55. The print head itself, designed for easy replacement by the user at a cost of $20.00, has an estimated life of 4.2-million characters (approximately 2,000 single-spaced pages).

IBM rates the Quietwriter's burst printing speed at 40 to 60 cps depending on pitch, a rate that allows reasonable throughput despite a leisurely paper-feed rate and slow carriage return movements. For example, a dense page of single-spaced text is turned out in 1 minute 45 seconds.

Character generation is controlled by *electronic font modules*, one-inch square, plastic-encased ROM units that are plugged into two sockets under the printer's hinged main cover. One of the sockets holds the primary module, which dictates the character set, font, and pitch used by the printer in normal operation. When font modules are installed in both sockets, the printer can be switched back and forth between them under software control.

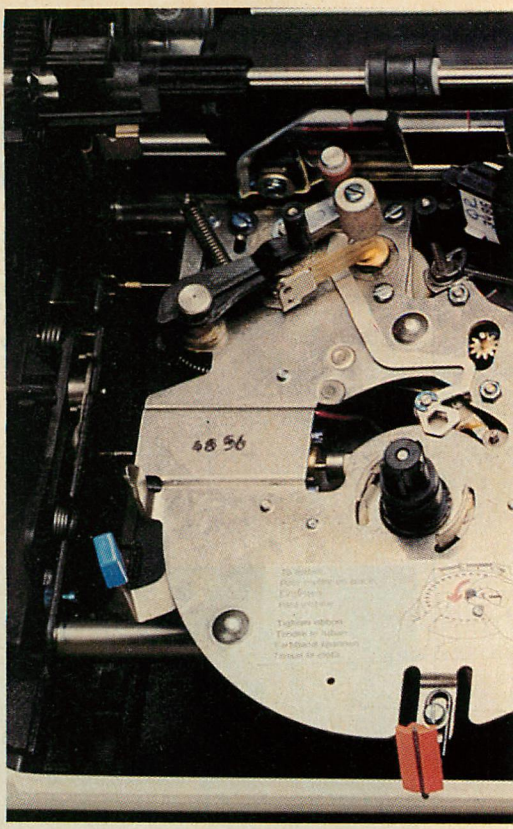
A one-handed motion slides the font modules effortlessly into and out of the spring-loaded sockets. The standard, PC-compatible modules contain the full, 252-character IBM PC character set in Courier, Prestige, and Boldface styles, and they are available in 10-, 12-, and 15-pitch versions as well as for proportional spacing. Most of the more than two dozen modules available for the Quietwriter typewriters may be used with the Quietwriter printer as well; font modules are $50.00. (Using font modules is the only way to control the Quietwriter's typeface—no "soft" character set loading is supported.)

The Quietwriter cannot print all graphics, but with its full IBM PC character set, it can print any figure that can be produced on the monochrome display, including line graphics.

In its standard configuration, the Quietwriter provides friction paper feed. A pinwheel form feeder, a must for any sustained use of continuous forms, can be added for $75.00; in addition, an automatic single-sheet feeder is available for $375.00.

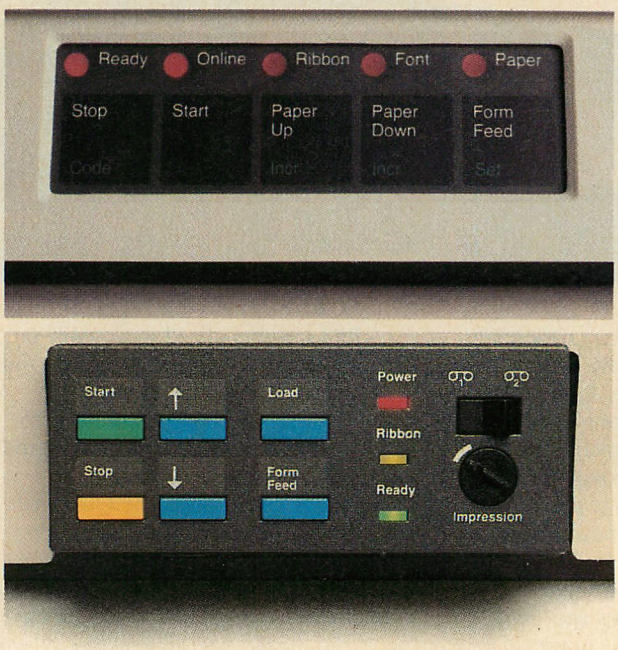
The Quietwriter's basic controls are simple and typewriter-like. The ingeniously designed operation of the paper bail control lever simplifies hand-feeding single sheets of paper. To load a sheet of paper, the operator needs only to insert the paper behind the platen and pull the paper bail lever forward (lifting the rollers off the surface of the platen). The printer then seizes the sheet of paper and rolls it up under the print head. The bail remains up until the first six or eight lines have printed, then springs down to hold the paper securely against the platen as printing continues.

The printer is easily used with software that is unaware it is running a hand-fed printer. Lifting the paper bail

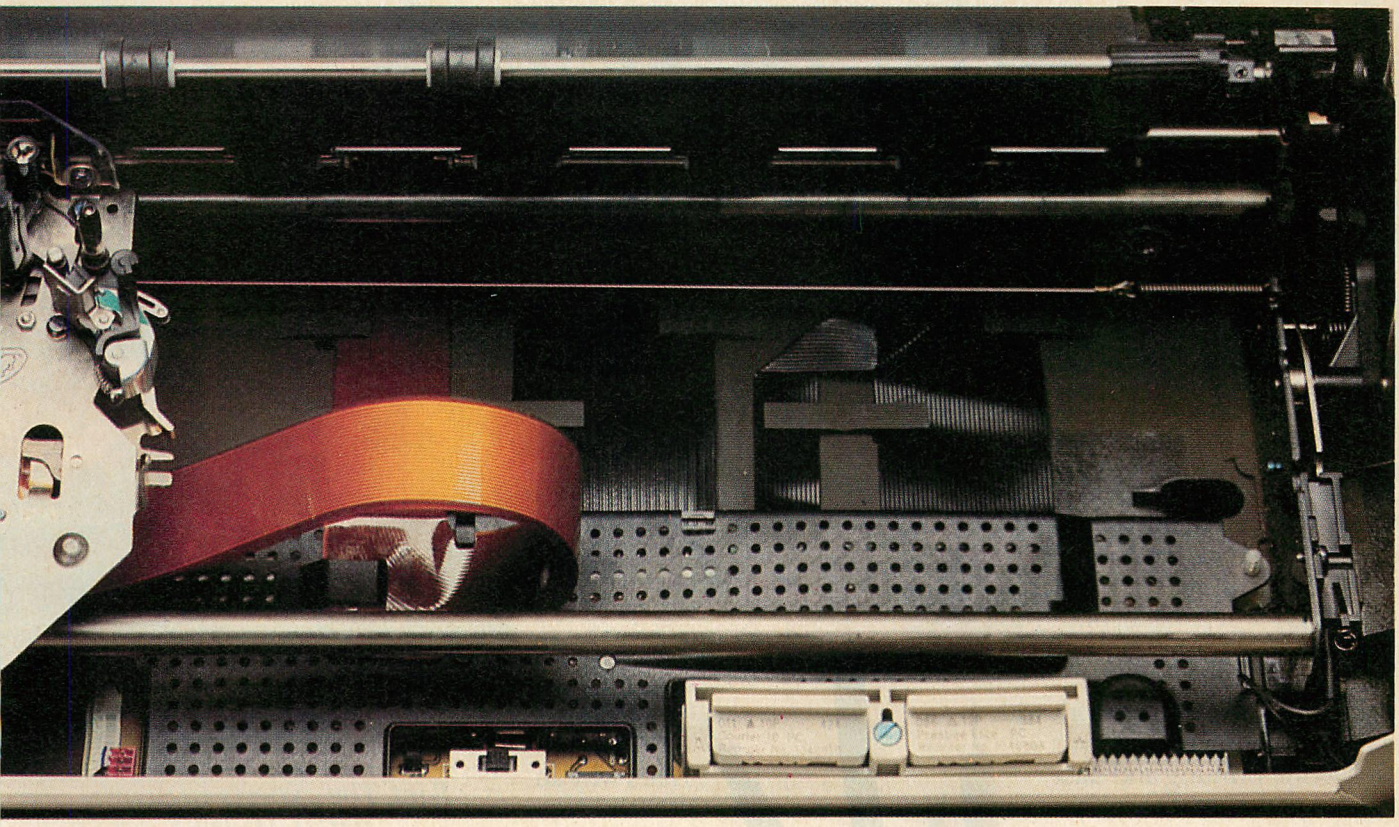


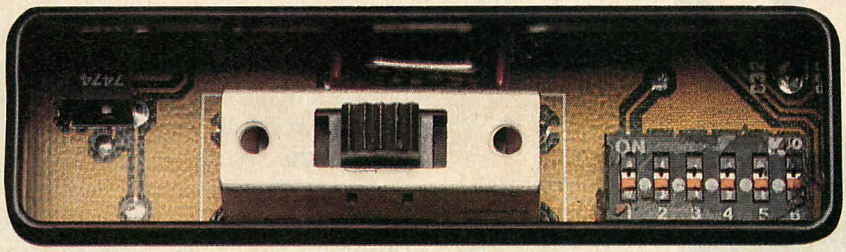
while pressing the Stop control places the printer in Auto Stop mode; once in this mode, the printer automatically drops off-line and beeps to await the insertion of a new sheet of paper after printing each page.

The control panel, located on the front of the machine, contains five membrane switches: Stop, Start, Paper Up, Paper Down, and Form Feed. All paper adjustment is accomplished by using the Paper Up and Paper Down buttons which move the paper in 1/96-



The control panels: the Quietwriter has five membrane switches on its panel (top photo), located on the front of the printer. Five lamps indicate ready and on-line status and warn of font, ribbon, and out-of-paper error conditions. The Wheelprinter sports six push-button controls. The extra control is Load, used after manual insertion of single sheets to position the first line of the paper under the print head automatically.





The Quietwriter is distinguished by its lack of noise, a result of the thermal print mechanism and new-technology resistance ribbon it uses. It has a contrast control switch (which is pictured at left) with three settings to control the boldness of the printed text.

inch increments. The Stop button doubles as a shift key for the Paper Up, Paper Down, and Form Feed controls. Shifting the Form Feed button allows resetting the top-of-form position. Five lamps indicate ready and on-line status and warn of font, ribbon, and out-of-paper error conditions.

Software interface is almost identical with that of the IBM Graphics Printer. The Quietwriter lacks only the graphics capabilities and compressed and emphasized text modes of the standard Graphics Printer (see table 1). Most documents produced by programs designed for the Graphics Printer have the correct format and appearance when printed on a Quietwriter.

The standard Quietwriter comes equipped with a parallel, Centronics-type electrical interface; serial interface is available as an option.

The Quietwriter is light and compact, weighing 22 pounds and measuring 21.3 by 14.4 by 6.5 inches. Its *Guide to Operations* document is clear and complete, copiously illustrating unpacking, configuration, and operating instructions and outlining extensive problem-determination procedures. With its usual attention to detail, IBM includes, clip-mounted inside the Quietwriter case, a special dummy interface connector for use in the self-diagnostic wrap test. More detailed information on product specifications, electrical interfaces, and circuitry is available in an optional *Technical Reference* document.

WHEELPRINTER FLEXIBILITY

It does not approach the sounds of silence of its sibling Quietwriter, but the more expensive Wheelprinter (model 5216) also scores points for noise reduction. Although it uses an inherently noisy daisywheel/impact printer, its high-speed print hammer has been held to an estimated 59 dBA by an acoustically engineered case; it is quieter than most daisywheel printers.

The new Wheelprinter is only distant kin to its older namesake, the 5218 Wheelprinter. Lighter, slower, quieter, and much cheaper, the new model is aimed squarely at the PC market. The 5218 serves multiple systems in the Displaywriter and office systems product lines; the 5216 is a one-PC printer.

Paper-handling versatility is the strong point in the Wheelprinter's design. Excluding the tray, the mechanisms providing continuous form/tractor feed, hand-fed, single-sheet feed, and automatic single-sheet feeding are enclosed by the printer case and coexist in a small space. The printer is switched among paper-feed modes by manipulating one toggle switch and a set of paper gates and doors. The switching procedures require close adherence to the instructions, but they are easily mastered. The printer operates reliably, rarely jamming in any mode.

The Wheelprinter's case is larger and boxier than the Quietwriter's. At 33

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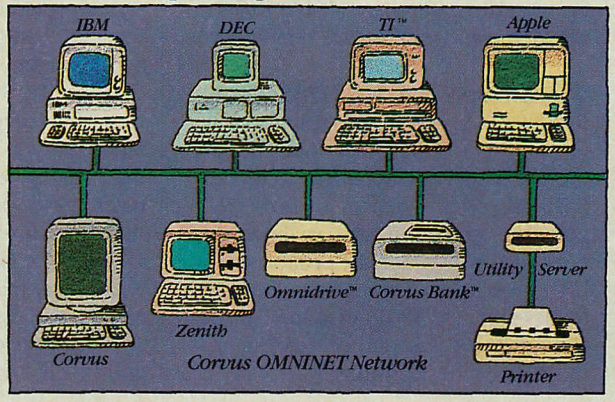

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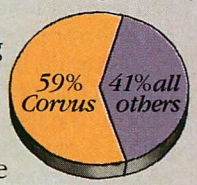

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CIRCLE NO. 127 ON READER SERVICE CARD

pounds, the machine is also a good bit heavier and looks and feels much more solid than the Quietwriter.

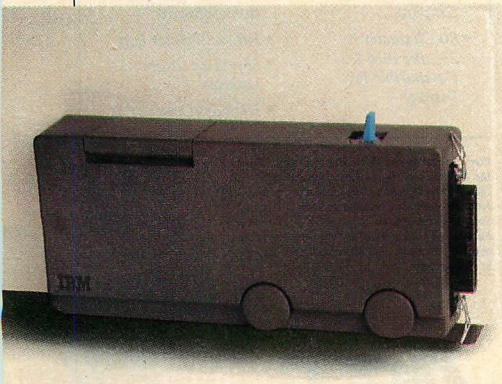
The Wheelprinter prints characters at a burst rate of 25 per second at 12 pitch. The modest rating is deceptive, however, because bidirectional printing and a lively paper transport system actually provide very respectable throughput. In fact, the Wheelprinter finishes in a dead heat with the twice-rated Quietwriter on documents that are longer than two or three pages.

The control panel has six push-button controls: Start, Stop, Paper Up, Paper Down, Form Feed, and Load. Like the Quietwriter, the Wheelprinter has no platen crank knobs. The Paper Up and Paper Down buttons allow form alignment by whole-line or one-line increments; shifting them with the Stop button allows rapid movement in either direction. The Load control button is used after manual insertion of single sheets, in order to position the first line of the paper under the print head automatically.

A print intensity control, also located on the main control panel, allows adjustment of the print head's striking force to achieve desired print appearance, print wheel life, and ribbon life with different types of paper and different print wheel styles and pitches.

The Wheelprinter allows selection between two ribbon-feed rates via a two-position rocker switch. The slower rate gives longer ribbon life and slightly lower print quality; the faster rate yields maximum print quality but reduces ribbon life to about two-thirds of that achieved when using the slower rate. The large (6-by-7-inch) ribbon cartridges load and unload easily and are available in two styles: a high quality, one-pass ribbon rated at 138,000 character impressions (55 pages), and a reusable, draft-quality ribbon, good for a half-million characters (200 pages).

More than two dozen print wheels (all of which are interchangeable with those for the Wheelwriter typewriters) are available for the Wheelprinter in IBM's new Cartridge Printwheel II series, in 10-, 12-, and 15-pitch and for proportional spacing.



Configuring the Wheelprinter for parallel or serial electrical interface to the controlling computer is a simple, straightforward process, unlike most other printers that can be equipped with either interface. The user configures the printer for either parallel or serial interface by installing one of two system attachment units on the rear panel. These compact units, which contain interface electronics, a host system data connector, and configuration switches appropriate to the interface type, are secured to the printer case with a hook-and-loop panel and two thumbwheel screws and mate with a data connector on the rear of the printer case. Installation and configuration can be accomplished in a few minutes.

The parallel system attachment, the printer's standard interface, carries 12 option switches that select default pitch, country code (for character-set modification), auto-line-feed after carriage re-

The Wheelprinter can be configured for parallel or serial electrical interface by installing a system attachment unit on the rear panel.

TABLE 1: *Control Code Compatibility*

IBM GRAPHICS PRINTER FUNCTION	ASCII	DEC	QUIET-WRITER	WHEEL-PRINTER
Cancel ignore paper end	ESC 9	57	X	–
Cancel skip perforation	ESC O	79	X	–
Carriage return	CR	13	X	X
Compressed characters	SI	15	*	*
Compressed characters off	DC2	18	*	*
Double strike	ESC G	71	–	–
Double strike off	ESC H	72	–	–
Double width (one line)	SO	14	X	–
Double width	ESC W	87	X	–
Double width (SO) off	DC4	20	X	–
Emphasized	ESC E	69	–	–
Emphasized off	ESC F	70	–	–
Form feed	FF	12	X	X
Home head	ESC <	60	–	–
Horizontal tab	HT	09	X	X
Ignore paper end	ESC 8	56	X	–
Line feed	LF	10	X	X
Paper feed	ESC J	74	–	–
Select character set 1	ESC 7	55	X	X
Select character set 2	ESC 6	54	X	X
Set horizontal tab stops	ESC D	68	X	X
Set length of page	ESC C	67	X	X
Set lines per page	ESC C	67	X	X
Set skip perforation	ESC N	78	X	–
Set var. line feed (1/216 inch)	ESC 3	51	–	–
Set var. line feed (1/72 inch)	ESC A	65	X	*
Start var. line feed	ESC 2	50	X	X
Subscript/superscript on	ESC S	83	X	X
Subscript/superscript off	ESC T	84	X	X
Underline	ESC –	45	X	X
Unidirectional printing	ESC U	85	–	X
Set 1/8-inch line feed	ESC 0	48	X	X
Set 7/72-inch line feed	ESC 1	49	X	X
(Graphics)	ESC K	75	–	–
(Graphics)	ESC L	76	–	–
(Graphics)	ESC Y	89	–	–
(Graphics)	ESC Z	90	–	–

X Printer interprets code exactly as IBM Graphics Printer does
** Printer recognizes code but performs a different function*
– Printer does not recognize code

Quietwriter and Wheelprinter recognize many control codes of the IBM Graphics Printer, though some are interpreted differently. Not all codes are presented here.

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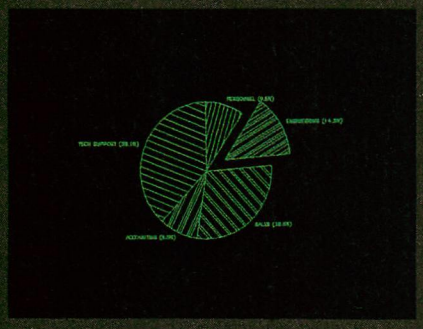
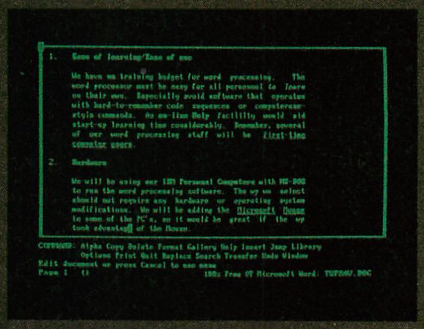
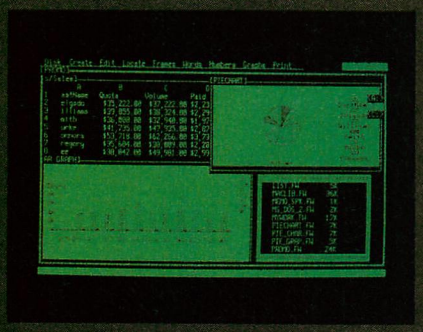


SYMPHONY ™

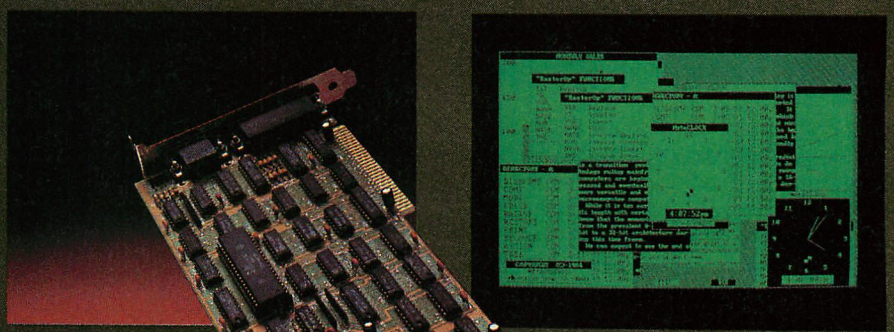


WORD ™

1-2-3 ™



FRAMEWORK ™



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- *Standard IBM Character Set*
- *Compatible With Popular Bit-Mapped Graphics, Text and Windowing Applications Software*
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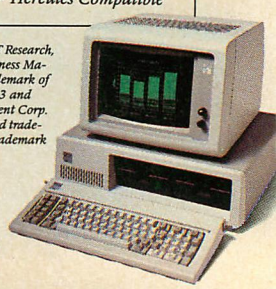


AST RESEARCH INC.

turn, audible alarm enable/disable, and self-diagnostic test sequences for the attachment and for the printer. A three-position switch on the attachment selects single-sheet, continuous form, or automatic sheet-feeder paper transport.

In software interface the Wheelprinter is compatible with the older 5218 Wheelprinter. It also shares some control codes with the IBM Graphics Printer, but the codes interpreted identically by the two machines is limited (see table 1). *Some* programs written for the Graphics Printer will operate the Wheelprinter correctly, but only those that stick to a minimal subset of the Graphics Printer command set. Incompatibilities exist among the commands common to the two printers. For example, any program that uses the Graphics Printer command to set the length of a line-feed movement will not produce correctly formatted documents on the Wheelprinter; the Graphics Printer expects a distance specification in 1/72-inch units, while the Wheelprinter expects it in 1/48-inch units. Limited compatibility notwithstanding, the Wheelprinter software command set is extensive and flexible, providing support for proportional spacing, status and exception reporting (serial interface only), printwheel table downloading, and direct and buffered print modes.

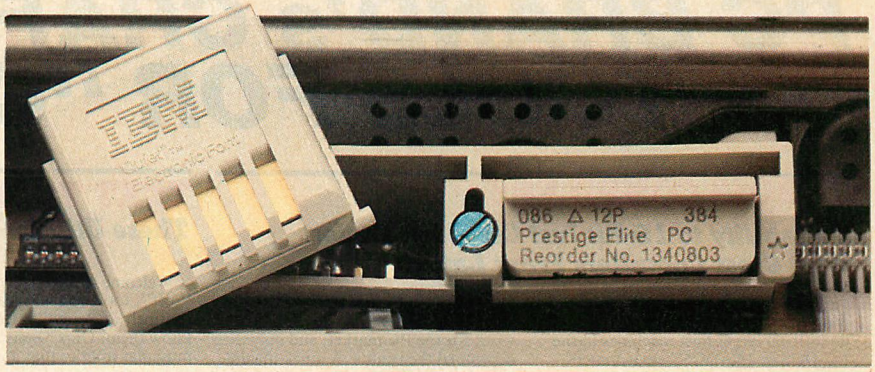
The Wheelprinter's half-inch-thick *Guide to Operations* document is a clear and comprehensive reference, both for those operating the printer and for those requiring software or hardware interfacing specifications.

UPTOWN APPEAL

Of the two printers, the Quietwriter is the technological newsmaker, with its first-of-a-kind resistive ribbon. The Wheelprinter is more subtly distinguished by the excellent engineering of its paper handling, acoustic case, and modular data interface units.

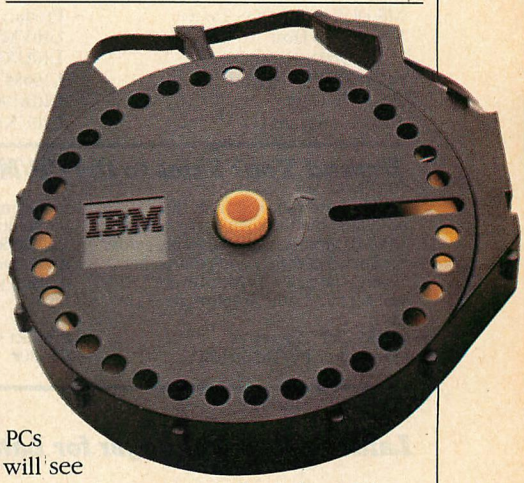
The $1,395 Quietwriter and $1,795 Wheelprinter are aimed at different but substantially overlapping markets. Their $400 difference in price vanishes when equivalent configurations are considered: adding continuous form feed and automatic sheet feed options to the Quietwriter brings its price to within $20 of the cost of the Wheelprinter.

The simpler, cheaper standard configuration of the Quietwriter, its light weight and compactness, and its high level of PC compatibility make it attractive to the uptown side of the personal computer market. On the other hand, its high speed, nearly perfect letter quality, and automatic sheet-feed option make it a strong contender in any small or large office setting. Its quietness alone will help make the purchasing decision for many office managers because it will save them the expense and bulk of a sound-deadening enclosure, and it will open new, step-saving placement options.



The Quietwriter has two electronic font modules that plug into sockets located under the printer's main cover.

The Quietwriter's ribbon (shown below) is encased in a bulky cartridge that is easy to replace.

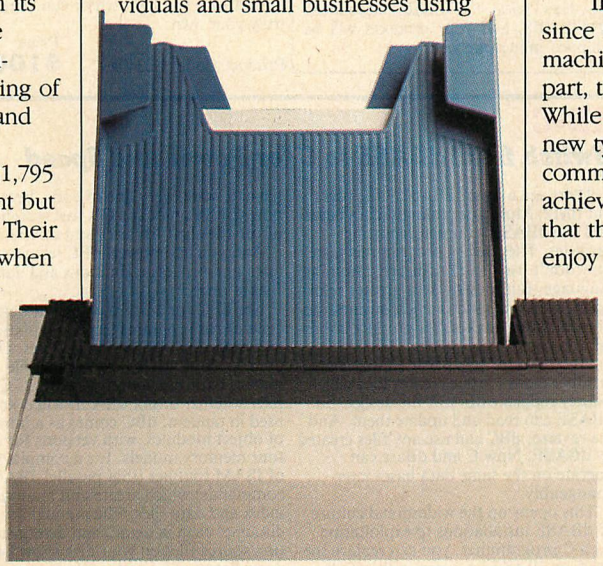


The only significant drawback of the Quietwriter, in comparison to the Wheelprinter, is its inability to switch quickly among paper-feeding modes, as the Wheelprinter does so well; the Quietwriter's pinwheel feed and automatic sheet-feed options cannot be mounted at the same time.

The Wheelprinter is more clearly aimed at business users, but it remains within the sight of the high-end, individual computer user. Its paper-handling dexterity, smooth operation, and fully formed characters make it an ideal middle-volume office machine.

It is worth noting that some individuals and small businesses using PCs will see an opportunity in the flexibility of the Quietwriter and Wheelwriter *typewriters*, as well. These can be adapted to operate as computer printers by adding a $210 attachment. The adapted typewriters are not as fast or as flexible as the dedicated printers; nevertheless they could serve a low-volume home or office in the dual role of typewriter and printer very economically.

IBM has certainly come a long way since introducing the original Selectric machine and its cumbersome counterpart, the 2741 printing data terminal. While it remains to be seen whether its new typewriter products will rise to command the market dominance achieved by the old Selectrics, it is clear that these two excellent printers will enjoy long and widespread use.



The Wheelprinter's paper-handling mechanisms fit compactly together and integrate well with the printer.

Quietwriter: $1,395
Wheelprinter: $1,795
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Richard M. Foard is vice president of software development for ROADNET Systems Corporation.

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C-SPRITE

Lattice's Own Debugger for Lattice®C

This versatile companion to your compiler gives you the best of both worlds for an out of this world price. Hand it a COM or EXE file produced by the Lattice Compiler (using the -d option) and C-Sprite™ will speak your language: your function names, your variable names, your data types, and the line numbers from your source code. At the same time, if you want to scrutinize just what machinations the compiler (or an assembler) has contrived, you can get a close-up view of machine addresses and machine coded instructions.

You can set simple breakpoints using symbols or addresses, or submit clusters of commands to be executed at the breakpoints, or set commands that execute until a condition is met.

You already know how to converse with C-Sprite, if you are familiar with Microsoft's Debug. Lattice began with that well-known command language, and then added to it considerably: You can work with data in hex, as you might expect, and you can also differentiate between C's data types, causing the debugger to treat addresses as pointers, or strings, or long integers, etc., both in display and entry. C-Sprite even has macros — use your source code variable names in a macro to dump the contents of entire C structures, for example. And you can debug through one of the COM ports with a second terminal so as not to disturb your program's display screen. What's more, if you link with Plink86™, C-Sprite can even tackle overlays.

Program doctors will find plenty of implements to rummage through in this kitbag.

Price:
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TEXT TOOLBOX™ #1

These Utilities Work Wonders of Organization

Welcome to "grep", "wc", "ed" and "diff", tools you will reach for as routinely as "copy" once you come to know them. Unix™ boasts a number of muscular utilities that are migrating to the PC world. Lattice has assembled this cluster of the most useful text management tools into a single package.

"Grep" looks for text patterns in any number of files. Its powerful expression syntax goes far beyond your text editor's search command. Use of "(.+)" with "*.c" will find in all files with ".c" extensions all lines with parenthesized expressions, no matter how many characters lie between. Want to find all function calls? Look for all occurrences of, say, a global variable throughout a program system? Search for all programs in a directory, use paths to other directories? Find all files on a disk? "Grep" will grab them all.

"WC" counts lines, words, and characters in a file and has a checksum independent of machine character sets so you can test whether a file has een transferred successfullybetween computers.

"Ed" is similar to the well-known Unix editor. It offers search and replace with "Grep's" syntax, block move, read and write, optional line numbering, append, insert, delete, and this unusual facility: you can instruct "Ed" to apply a file of commands to any number of target files, even complicated changes and text additions, such as those created by "Diff".

"Diff"? You've probably tried to write one (and then discovered how tangled the logic gets). "Diff" compares text files line for line and reports differences. It uses complex algorithms to re-synchronize between files after disparities involving any number of lines are found. And it outputs a precise list of instructions telling what to do to make two files exactly the same, a list which can be handed to "Ed" to do the job!

You'll ultimately find such assistance indispensible. Like having a librarian to sort out the confusion every day and keep your work tidy.

Price:
Product Code: L2220# **$120**

CVUE

A Text Editor to Make Your Own

CVUE is a neat screen oriented text editor which does most of the things that a good editor should do, such as automatic scrolling vertically and horizontally, insertion and overtype entry modes, block delete, undelete and move, and full DOS 2.0 directory path name support in reading and writing files.

It is easy to learn with a comprehensive command menu screen which makes the documentation an ornament. It was written by the Lattice programmers who felt forgotten by the folks who write WP software. They needed easy entry of non-display characters such as control codes and escape sequences, not footnotes. Indenting and Undenting of block structures loomed larger than italic printing for them. Pattern searching won out over spell checking. So CVUE was born.

CVUE has its limitation. It only supports in-memory text files, but with memory at today's prices, creating and maintaining files of over 500 KBytes long is practical. Anyway, modular source code of structured programs never gets nearly that big. As compensation, CVUE is very compact and fast. It actually runs in computers with only 64 KBytes of memory and uses no tediously slow overlays to perform its full function repertoire.

The power of CVUE is its ease of customization. Even with only a binary license, full customization of the keyboard editing commands is offered. And when you take advantage of the Source Code option (found elsewhere in this ad.) the resultant editor can be made truly your own.

Price:
Product Code: L2240# **$100**

dB-C

Switch from dBASE to C for Power and Speed

There are a lot of dBASE™ file users out there. Most just maintain data bases and use dBASE's limited reporting facilities. They're not programmers, so they don't use the dBASE programming language. But they'd like a greater return on their efforts, and that's a business opportunity that makes this product important to you.

dBC™ links C to dBASE. This new product from Lattice creates files which exactly replicate dBASE file design. So dBASE can read and update them. And the reverse. dBC can use any files created by dBASE. Now C and dBase can operate on the same data bases interchangeably.

This opens up the widespread culture of dBASE installations to exploitation. As a C programmer, you can replace the resident dBASE language with speed! Both C's and your own: you no longer have to write every line of code, because now you've unlocked C's vast storehouse of off-the-shelf libraries and utilities.

And you add power: dBC lets you open and process eight index and data files at once.

Use dBC for custom work. Or design generalized programs for manipulation and reporting of dBase data bases. Or use it on its own. It's a complete file manager for use with the Lattice C Compiler whether or not dBASE will ever be used in tandem. dBC comes as a library of object modules, with versions for all four memory models. It's a complete set of ISAM routines (that parallel dBASE commands) which create and maintain index and data files. The manual discusses each in detail, and demonstration source files on your disk show how every function is used.

Two Versions:	Product Code:	Price:
Dbase II Compatibility:	L00II#	**$250**
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CURSES

A Screen Management Interface to Swear By

Curses is a Lattice creation which manages the screen of the IBM PC in the same fashion as the curses utility of Unix and similar operating systems. Use it to adapt programs which call Unix's curses functions for screen management, and need the equivalent library when moved to the PC for re-compilation. Or use it when creating software on the PC to assure that it is Unix compatible.

Curses is a library of eighty-four functions and macros which can keep any number of screen images in memory.

Within a screen, Curses employs a vast function set to get characters, wrap lines, scroll, blank lines, highlight — virtually every tool needed to update the screen. The product supports color, and all four memory models. In keeping with the terminal orientation of Unix curses, the physical screen is re-painted (at high speed) only when your program calls a refresh function.

Writing screen management code leads to unspeakable snarls and expressions. Swear off! Let Curses clean up your language.

Price:
Product Code: L0850# **$125**

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CODE SIFTER
Find the Hot Spots in Your Program

Fast is never fast enough; only miracles need apply. That's what's expected in today's marketplace, so our Code Sifter is an important tool to add to your workbench.

Code Sifter finds the trouble spots in your program. On its own, it will divide a COM or EXE file of any size into thirty-two equal partitions. Alternatively, you can specify the partition boundaries with addresses, or with symbols if your linker has produced a symbol map. Then tell Sifter to run your program. It samples your object file at precisely timed intervals and counts how many times it finds the instruction pointer in each partition. Job done, it reports the number and percentage of hits in each partition.

You are in for some surprises when you discover just how unbalanced the activity is likely to be, and that's why Code Sifter is so valuable. It profiles just where you can best spend time optimizing your code, or even converting to assembler subroutines.

Code Sifter has a number of monitoring options. You can tell it to include any combination of your program, DOS, and BIOS in its analysis. You can specify the sampling rate. Most important, you can tell Code Sifter the number of times to run a program, and between each run discard the less active ranges and repartition the hot spots, so that you zoom in ever tighter on small areas of code. Right down to the last byte! Literally. Try it on the sample program that comes with your disk.

Code Sifter. It will give you the racer's edge.

Product Code: N3100# — Price: **$119**

USED COMPILERS WELCOME
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Has your compiler run out of gas? Has your model been discontinued? Is it falling behind for lack of new parts?

Even if yours is in good shape, you have surely noticed there are more options and accessories produced to run with the Lattice C Compiler than any other. Don't do without these additives any longer. It's time for new license plates. Trade in your original disks and manual of any of the compilers below and we'll send you Lattice's most up-to-date model, the full bore 2.14 (at press time).

From then on you will be adopted by Lattice for full, direct support by their technical specialists.

Product Code LU150:	Price:
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Product Code LU200:	
Computer Innovations C86	**$200**
Manx Aztec C86	**200**
Mark Williams C	**200**
Wizard C	**200**
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Whitesmith's C	**200**

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for MS-DOS/PC-DOS	L9100#	**$500**
for Z80	L910Z#	**500**
C-Food Smorgasbord Library	L9200#	**500**
Curses Library	L9850#	**125**
dB-C Library		
for dBase II	L90II#	**250**
for dBase III	L9III#	**250**
CVUE Screen Editor	L9240#	**350**
Text Toolbox #1	L9220#	**120**

LMK
A Unix-like "Make" Makes Light of System Building

If you have ever built a complex system, you know the time loss and tedium of recompiling, rebuilding libraries and relinking modules because a snippet or two of code has changed. Batch files are no answer. You need batches of them to avoid redoing everything indiscriminately.

Instead, imagine making a change deep in a system, and simply telling Lattice's LMK™ to take over. No further thinking or keystrokes. LMK will rebuild your final product, however involved and complex, by doing just what is needed and no more.

How? You write a command file which expresses bottom to top all the elements comprising your system and all its dependencies: what gets compiled to make what object file using what options; what is built into libraries; what is linked into the final EXE file. Through the life of your system, LMK keeps track of the last time every action was performed. Run LMK and, tracking each branch, it looks only for elements which changed later than a dependent element further along the branch, using date and time information found in the file directory. Any source file newer than its object file, for example. Only those elements and their dependents are remade. All other instructions are bypassed.

The command file uses a simple, readable syntax — "prog.obj: prog.c $(HDRVS)", for example, says what source file this object file depends on, and fills the previously defined macro HDRVS into the expression, which here might be a list of files with hardware drivers, or in another case your preferred string of compiler options.

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The new IBM Enhanced Graphics Adapter (EGA) should satisfy a lot of cravings: it supports more displays, more modes, more memory, and more colors than either of the original PC display adapters, is more highly integrated, more flexible, more expandable, and, of course, costs more money.

The EGA is a graphics controller that supports either color or monochrome direct drive monitors in a variety of modes. The EGA supports three different display types:

- IBM Monochrome Display or equivalent 350-line high-resolution display (such as the Amdek 310 or 310A)
- IBM Color Display or equivalent 200-line TV frequency IRGB display
- IBM Enhanced Color Display

Unlike the IBM Color/Graphics Adapter (CGA), the EGA does *not* support composite monitors, VCRs, or television receivers, nor does it have a built-in printer adapter like the IBM Monochrome Display.

The EGA supports all of the display modes provided by the original IBM adapters and adds its own:

- 640-by-350, 4-color graphics on the monochrome adapter (the four colors are black, normal, bright, and blink)
- 320- and 640-by-200, 16-color graphics on standard frequency IRGB displays
- up to 640-by-350, 16-color graphics on the Enhanced Color Display
- a programmable color palette that allows any color attribute to be mapped into any of 16 colors on IRGB displays (8 colors on RGB displays), or any of 64 colors on the Enhanced Display
- a flexible, RAM-based character generator that supports up to 512 character codes, with BIOS support for alphanumeric displays of up to 43 lines of 80 columns on high-resolution (350 scan lines) displays

- hardware support for smooth horizontal and vertical scrolling
- hardware support for split screen displays (separate, noncontiguous buffers for two adjacent display regions)
- light-pen interface compatible with previous IBM adapters
- hardware support for fast display updates, multiple modes for writing to display memory, and capability for interrupt on vertical retrace

The most obvious improvements are the new color palette, monochrome graphics, and the Enhanced Color Display. These and other features should be examined from several viewpoints: functional, physical, architectural, experimental, and financial.

The functional aspect of the EGA depends on the type of display used with it. The visual attributes vary with the display and the amount of graphics memory installed.

The monochrome display has only two video inputs, video and intensity, which gives four possible combinations. Although four intensity levels might be expected, the intensity input by itself displays as black, so only three colors are assigned to the monochrome display as is shown in table 1.

The color-display column in this table shows the parameters for standard TV-frequency displays. The IBM Enhanced Color Display is a dual-mode display, with the horizontal frequency controlled by the polarity of the vertical retrace signal. A negative polarity vertical retrace operates the Enhanced Color Display in high-resolution mode.

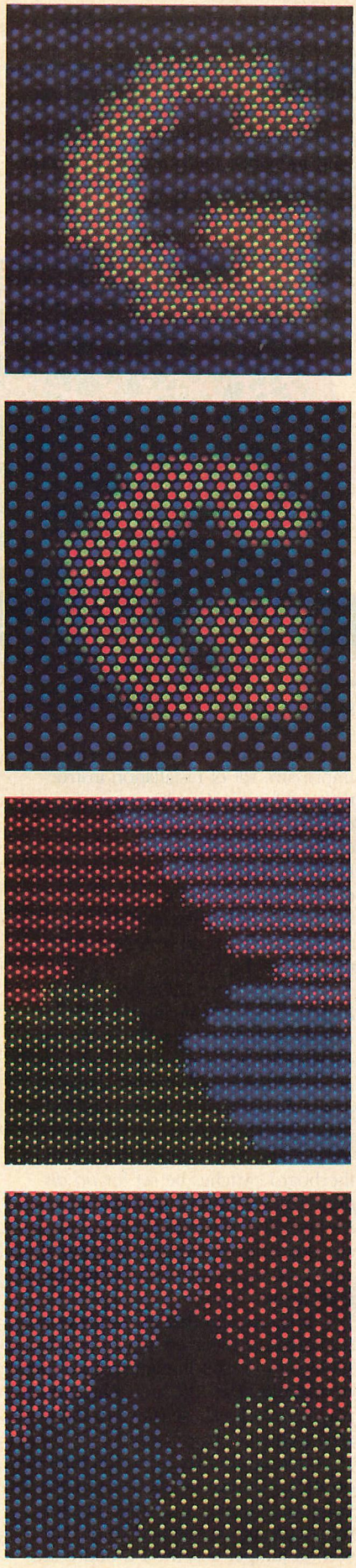
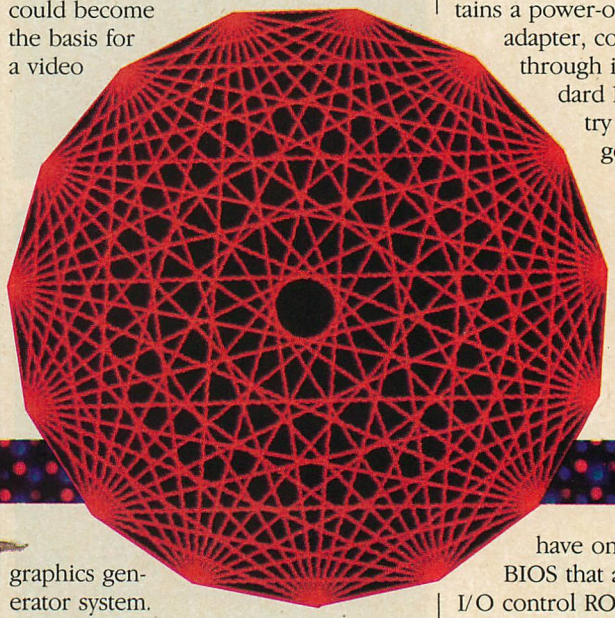
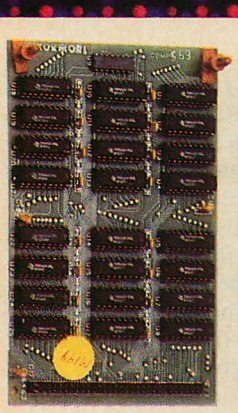


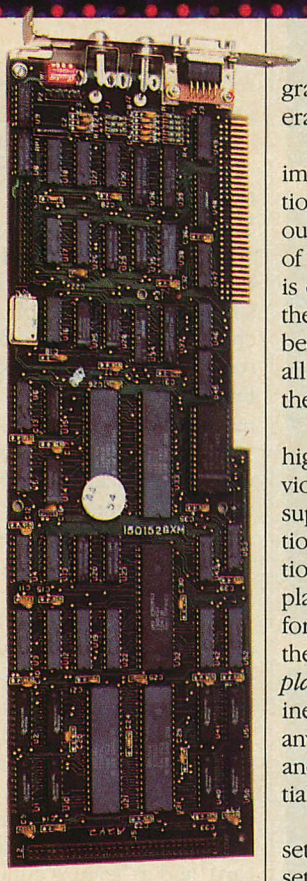
Table 2 shows the video operating modes supported by the EGA BIOS. Modes 0 through 7 are compatible with like-numbered modes in the original PC BIOS, but with enhancements. Mode 7 supports eight pages on the monochrome display. Modes 0 through 3 (color alphanumeric) display high-resolution 8-by-14 characters on the Enhanced Display if the EGA configuration switches are set for enhanced operation. CGA black-and-white modes 0, 2, and 4 are identical to EGA modes 1, 3, and 5. CGA did not generate a color-burst signal in the composite video output for black-and-white modes.

Physically, the EGA looks like any other full-size PC adapter. The rear panel has a nine-pin D connector for attaching a direct drive monitor, two RCA phono jacks not currently supported by the EGA hardware, and a hole through which four DIP switches can be accessed. The card contains two jumpers, a connector for the piggyback memory card, and a "feature connector."

Extreme close-ups show the difference between standard resolution (200 lines) and high resolution (350 lines) in text and graphics modes. Improved vertical resolution makes the individual horizontal scan lines all but invisible. All four photos were taken from an IBM Enhanced Color Display.







By using custom LSI circuits, the EGA (below left) packs more function in fewer chips than the Color Graphics Adapter. To the right of the EGA is the 64KB piggy back graphics memory expansion card. At right, a 16-sided polygon with all of its diagonals is shown in 640-by-350 graphics mode.

The feature connector provides a place where all monitor signals (six color bits, horizontal and vertical syncs, and blanking) and related adapter signals could meet the outside world. A feature board could supply an external sync and video information to the EGA, or it could combine the EGA signals with external sources. Thus, the EGA could become the basis for a video graphics generator system.

The adapter is packaged with an impressive set of installation instructions and manual update pages for various PCs (regular and AT) and versions of the *Guide to Operations*. Everything is clearly marked, but wading through the literature to find a particular version becomes a little tedious. The reason for all this trouble is those little switches at the rear of the card.

The on-board BIOS provides a high degree of compatibility with previously defined PC display modes, plus support for the new modes and functions. Unfortunately, the PC configuration switches have only two bits for display type. The EGA set-up procedure for PCs and XTs requires that the motherboard switches be set for *no display*. The EGA BIOS initialization examines the EGA switches to determine if any other display adapter is installed, and if so, which adapter is to be the initially active device.

It is *essential* that the switches be set correctly. Incorrect switch or jumper settings can result in damage to displays or adapters. The IBM Monochrome Display is notoriously sensitive to incorrect sync frequency or polarity.

One of the two 2-position jumpers on the card must be set one way for the Enhanced Display, the other way for monochrome or standard color. The second jumper sets the I/O addresses for the card to 2xxH instead of the standard 3xx. Thus, two EGAs can be installed in the same system. The supplied BIOS deals only with the card at 3xx; additional support has to be provided for the second card.

The EGA card has a 16KB ROM BIOS (which is twice the size of the entire PC system board BIOS) that contains a power-on self test for the adapter, code to support video I/O through interrupt 10H, the standard BIOS video function entry point, and character generator patterns for both alphanumeric and graphics modes. The EGA BIOS is located at segment C000H in the processor address space.

Because the EGA's BIOS is on the controller card, the PC must have on the system board a BIOS that automatically scans for I/O control ROMs. All ATs, XTs, Port able PCs, and new PCs have the correct BIOS. A PC with BIOS dated before 10/27/82 can be upgraded for about $30 from any IBM dealer.

The demonstration programs supplied to *PC Tech Journal* by IBM had creation dates between 9/83 and 10/84. The BIOS in the loaner board was a masked ROM dated 11/3/83, indicating that EGAs have existed for well over a year. The technical reference section for the EGA has August 2, 1984, printed at the bottom of each page. The BIOS listing in the technical reference is dated 9/13/84, which matches the version in the EGAs delivered to *PC Tech Journal* in January 1985. These adapters have Intel 27128 PROMs instead of masked ROMs. The IBM press release announcing the EGA was issued 9/10/84, three days before the latest BIOS revision.

FUNCTIONAL LITERACY

But enough archaeology. What can this tool do for us in modern times? A good place to start is with the functions provided by BIOS. The EGA initialization procedure places its own address in the INT 10H vector, after copying the original vector to the vector for INT 42H. The EGA BIOS can then call on the original BIOS for support of the old cards. This is the same technique used by the fixed-disk adapter to insinuate itself into the diskette service routines.

The accompanying sidebar, "EGA BIOS Functions," describes the functions provided via the EGA BIOS handler for INT 10H. Some of the new functions may look familiar to those who have seen the PC*jr* or PC/AT BIOS. The Set Palette Registers (Function AH=10H) is the same as on the PC*jr*, and Write String (AH=13H) is supported by the AT's system BIOS.

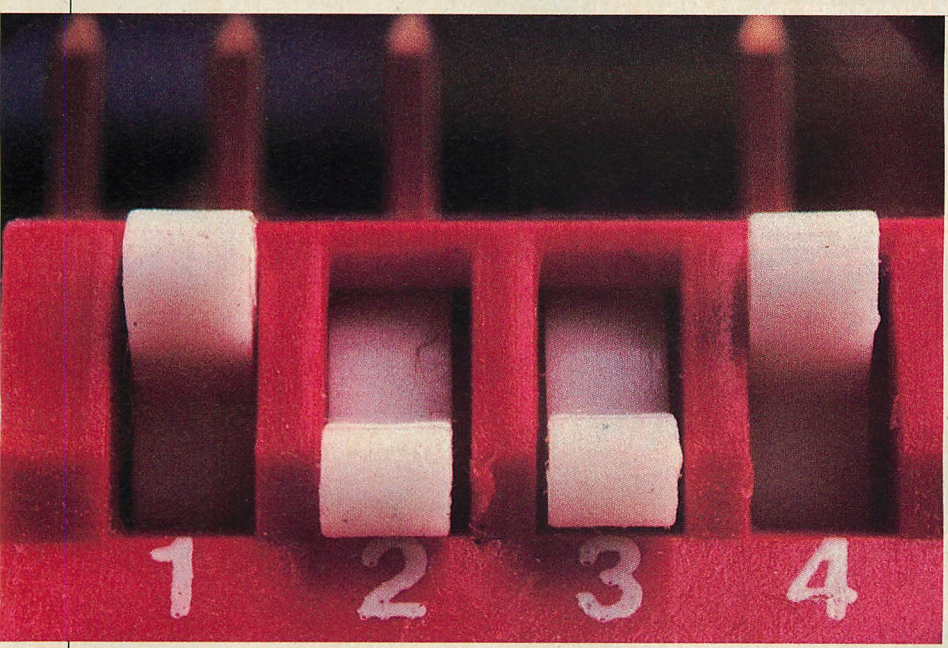
The two completely new functions are in support of the RAM-based character generator. In the previous display adapters, alphanumeric modes used the character codes in the display buffer to address a character generator ROM on the adapter. This ROM could not be read by the processor, thus the need for a copy of the character patterns in the BIOS ROM to enable software character generation in graphics modes.

The EGA BIOS contains two character pattern sets, one 8-by-14 for high-resolution displays, and the other an 8-by-8 set for TV frequency displays. Whenever an alphanumeric mode is selected (via function AH=0), BIOS copies the appropriate patterns into part of the EGA's memory, where the EGA hardware will access it just like the old adapters did their ROM character generators. But now the patterns can be anything the user wants—foreign languages, graphics symbols, etc.

Function AH=11H supports loading the RAM character generator from the BIOS ROM or from a user-specified place. The second set of functions will load the generator and recalculate the number of rows that will fit on the screen, after which BIOS will display text in the new format. This facility can be used to produce very readable 43-line-by-80-column displays on 350-line, high-resolution monitors by calling for the 8-by-8 character font. Listing 1 demonstrates how to do this and still have the underscore in the right place (a combination documentation/BIOS bug leaves underline register set one line past the bottom of the character cell when this function call is used).

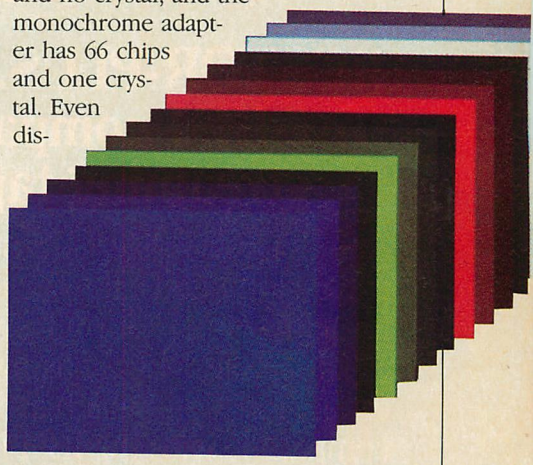
A related function in AH=12H replaces the print screen routine (through INT 5) with one that knows about the flexible screen dimensions.

The EGA BIOS uses the standard BIOS data areas (and additional areas) in segment 40H to record display-related information. Table 3 shows the EGA video parameter storage layout. One nice feature is the save area pointer at 40:00A8H. This double word pointer points to a table of pointers to user-selectable save areas in which BIOS stores the current values of additional parameters, such as the palette registers. This allows programs to work with the current values used by BIOS, many of which would otherwise be lost in write-only hardware registers. Table 4 shows the organization of save areas.



The EGA switches are used to set the initial operating mode. The 16 rectangles (shown above, right) show the three primary colors—red, green, blue— and gray in each of four intensities—off, low, medium, and bright; 64 combinations are possible.

The major components of the Enhanced Graphics Adapter consist of custom large-scale integrated circuits (LSI), reducing the chip count of the EGA to 52, plus one crystal and a few miscellaneous resistors and capacitors. By way of comparison, the CGA has 69 chips and no crystal, and the monochrome adapter has 66 chips and one crystal. Even discounting the duplicated CRT controllers and the printer adapter logic, the EGA does more than the other two cards combined with well under half the silicon. Three years of technology (not to mention a significant investment in custom logic) certainly makes the difference.



The major functional elements of the EGA are the CRT controller, the sequencer, two graphics controllers, the attribute controller, and the display buffer memory. The block diagram in figure 1 shows the relationship among these elements. The sidebar, "EGA I/O Register Summary," explains the I/O address map for all of the EGA registers.

The CRT controller generates the horizontal and vertical timing signals for controlling the CRT display, and the addresses for accessing the display buffer memory. The CRTC also generates cursor and underline timing signals and refreshing for the dynamic RAMs. The CRTC used in the EGA is a custom chip with some similarity to the Motorola 6845 used in the earlier IBM display adapters. Sufficient differences exist, however, so programs that try to set up the display dimensions directly, or adjust the image centering by fooling with the horizontal sync position, will probably end up with no visible picture.

The sequencer is another custom LSI device that generates the basic memory timings for the dynamic RAMs and the character clock for display refreshing. It coordinates memory access by the processor during active display

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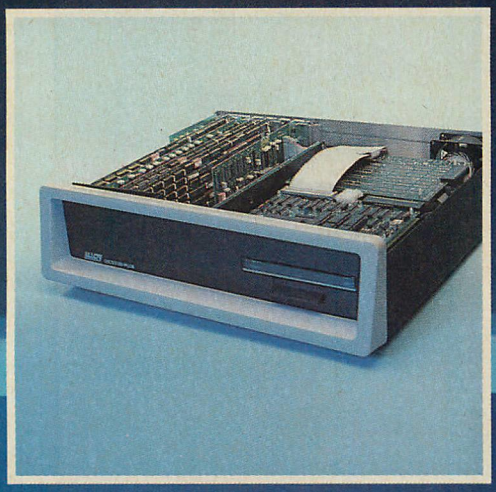

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times and contains a mask register that allows individual memory planes to be protected from possibly being written to by the processor.

The two graphics controllers direct the data from memory to the attribute controller and the main processor. In graphics modes, memory is sent in serial fashion to the attribute controller. In alphanumeric modes, the memory data are sent in parallel to the character generator plane or the attribute chip directly, bypassing the graphics controller. Each of the graphics controller chips handles two of the four bit planes. The graphics controllers work in parallel and share common I/O addresses.

The attribute controller is the fifth custom LSI device on the EGA board. It provides a palette of 16 colors, each of which can be set separately to control the six color outputs. This chip also controls the blinking and underlining functions according to the attribute bits in the display memory.

The display buffer memory is implemented using 64KB RAM chips that have an internal organization of 16KB by 4 bits. These are type 4416 chips, and are *not* the same 64KB RAM chips usually found in PC memory, which are typically organized as 64KB by 1 bit. The EGA card has eight 4416 RAMs, arranged in four groups of two. Each pair constitutes a 16KB bit plane. Additional display memory can be added on the piggyback memory expansion card. Each 64KB expansion (the card can hold up to three sets) adds another 16KB to each memory plane. The maximum memory supported is 256KB or four 64KB planes.

In order to support the variety of alpha, old graphics, and new graphics modes, the EGA has considerable flexibility with respect to memory access by the processor and display refresher logic. To begin with, the address of the buffer in the processor address space is programmable through the graphics controller miscellaneous register (port 3CF.06 bits 3 and 2) as follows:

Bit	
3 2	**Buffer Segment Address**
0 0	**A000H for 128KB—** *Not used by BIOS*
0 1	**A000H for 64KB** *New graphics modes (D-10)*
1 0	**B000H for 32KB** Monochrome alpha mode (7)
1	**B800H for 32KB** *CGA compatible modes (0-6)*

Bit 1 of this register has a further effect on memory addressing. When set to 0, all four planes occupy the same

TABLE 1: *IBM Monitor Parameters*

	MONO-CHROME	COLOR/ ENHANCED (TV frequency)	ENHANCED (High resolution)
Horizontal scan rate	18.432 kHz	15.750 kHz	21.850 kHz
Vertical scan rate	50 Hz	60 Hz	60 Hz
Video bandwidth	16.257 mHz	14.318 mHz	16.257 mHz
Displayable colors	3	16	64
Character size	7 × 9 pixels	7 × 7 pixels	7 × 9 pixels
Character box size	9 × 14 pixels	8 × 8 pixels	8 × 14 pixels
Maximum resolution	720 × 350	640 × 200	640 × 350
Alphanumeric modes	7	0,1,2,3	0,1,2,3
Graphics modes	F	4,5,6,D,E	10

The display used with the EGA determines its visual attributes. Features of the three IBM monitors that can be used with it are shown above.

TABLE 2: *EGA Operating Modes*

BIOS MODE	TYPE	ALPHA FORMAT	BOX SIZE	PIXEL RESOLU-TION	BUFFER START	COLORS	PAGE SIZE	MAX PAGES
0	Alpha	40 × 25	8 × 8	320 × 200	B800	16	2,048	8
1	Alpha	40 × 25	8 × 8	320 × 200	B800	16	2,048	8
2	Alpha	80 × 25	8 × 8	640 × 200	B800	16	4,096	8
3	Alpha	80 × 25	8 × 8	640 × 200	B800	16	4,096	8
4	Graphic	40 × 25	8 × 8	320 × 200	B800	4	16,384	1
5	Graphic	40 × 25	8 × 8	320 × 200	B800	4	16,384	1
6	Graphic	80 × 25	8 × 8	640 × 200	B800	4	16,384	1
7[1]	Alpha	80 × 25	9 × 14	720 × 350	B000	3	4,096	8
***8**	Reserved							
***9**	Reserved							
***A**	Reserved							
***B**	Reserved—Used by BIOS to load character generator (color)							
***C**	Reserved—Used by BIOS to load character generator (mono)							
***D**	Graphic	40 × 25	8 × 8	320 × 200	A000	16	8,192	2/4/8[2]
***E**	Graphic	80 × 25	8 × 8	640 × 200	A000	16	16,384	1/2/4
***F**	Graphic	80 × 25	8 × 14	640 × 350	A000	3	32,768	1/2
***10**	Graphic	80 × 25	8 × 14	640 × 350	A000	4/16[3]	32,768	1/2

[1] Monochrome alpha mode 7 supports three pixel intensities, but has eight attribute bits per character, which provide blink and underline in addition to foreground and background intensity selection.
[2] Max pages for modes D, E, F, and 10 depend on total graphics memory. First number is for 64KB, second for 128KB, third for 256KB.
[3] Mode 10 requires 128KB or more memory for 16 colors.

Modes 8, 9, A, B, C, D, E, F, and 10 (with asterisks) are supported by EGA. Modes 7 and F are for 50-Hz monochrome displays. Others are for 60-Hz color displays. Color modes with 350 lines require the Enhanced Color Display.

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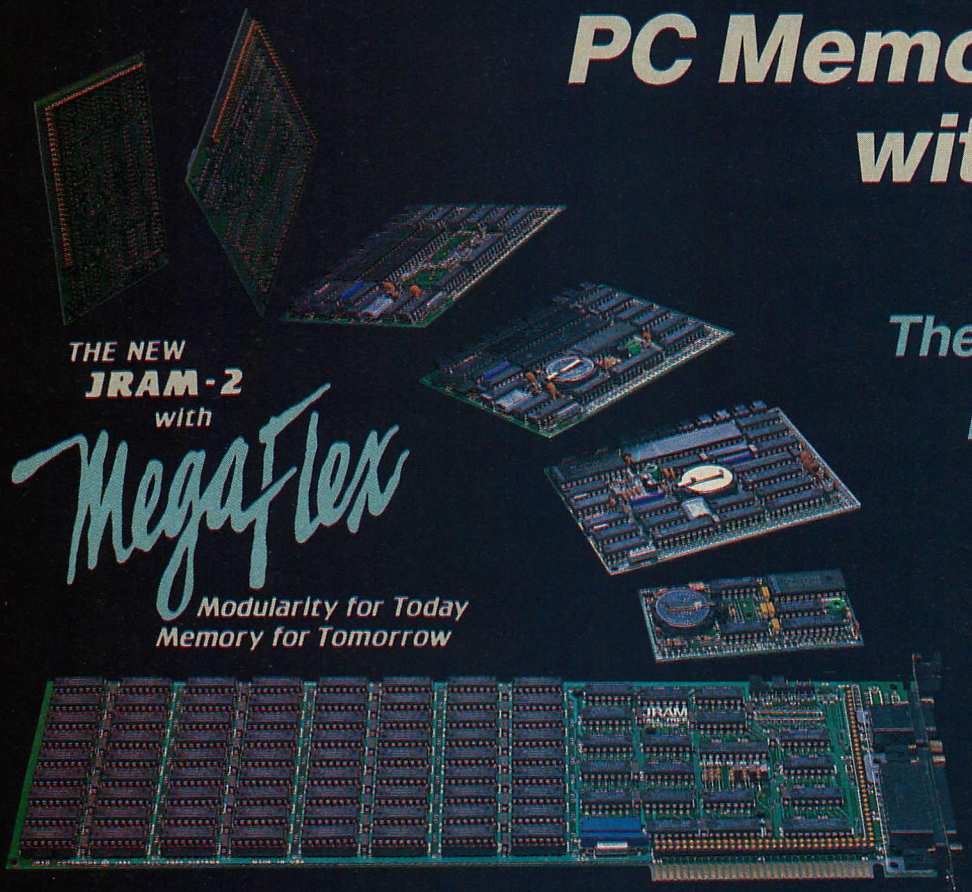

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region of the processor's memory address space and can be written simultaneously. In this mode the read map select register in the graphics controller (3CF.04) selects the plane to be read by the processor. When bit 1 is set to 1, map chaining is selected. This has the effect of placing plane 1 after plane 0, and plane 3 after plane 2, which doubles the available address space from the processor's viewpoint.

Bit 2 of the sequencer's memory mode register (3C5.04) controls sequential or odd/even interleaving. When set to 0, even processor addresses go to maps 0 and 2, and odd addresses go to maps 1 and 3. When this bit is 1, the data in all planes is accessed sequentially. Odd/even mode is used in conjunction with chaining in the alpha modes and the CGA-compatible graphics modes except mode 6 (640-by-200, two-color), which only requires a single bit plane. Chaining also is used (with sequential addressing) in the high-resolution graphics modes (F and 10) when only 64KB is installed to allow the processor to see a full 32KB buffer. Since this set-up has only two planes, high-resolution color graphics is limited to four colors with 64KB. With expansion memory installed, BIOS will set the memory for four parallel planes, giving full 16-color capability.

The important point here is that the compatible modes look the same from the processor's point of view as they always did, so programs that go poking around in screen memory will continue to work. (The CGA odd/even scan line offset of 8KB is controlled by the CRTC compatibility mode bit). One quickly develops a healthy respect for the job BIOS does in masking the hardware differences, which are considerable, between the adapters.

Figure 2 shows the memory organization and pixel arrangement for the EGA's new 16-color graphics modes. GRAPH16.BAS (listing 2) is a program for writing eight pixels at once for rapid painting on byte boundaries. Before running the GRAPH16 program, the E mode must be set by executing the SETMODE.ASM program that is shown in listing 3.

One of the nicer features of the EGA is its support for simultaneous display of any 16 colors from a palette of 64 colors. The CGA can also display 16 colors, but only those produced by combining the red, green, blue, and intensity signals.

The alpha foreground attribute field (the low order four bits of the attribute byte following the character code) can be used to illustrate the workings of the palette registers. In the CGA the attribute bits are sent directly to the I, R, G, and B pins of the monitor at the appropriate times, producing the specified color.

In the EGA the attribute bits are used as an index into the palette register array. The contents of the palette register is then sent to the monitor pins. Thus, the color that shows up on the EGA display depends on the contents of the selected palette register, not on the attribute bits directly. So, in a case where all of the palette registers are set to 0, the screen will be black, no matter what the attributes say.

Table 5 shows the arrangement of the bits in the palette register, and the corresponding pin positions on the direct drive monitor connector. When operating in enhanced mode (negative vertical sync and 350 lines) the IBM Enhanced Color Display recognizes six inputs corresponding to the six color outputs from the palette (see table 6). The R, G, and B signals produce dark colors, the R', G', and B' signals produce brighter colors, and the combinations produce still brighter colors. Thus, the four combinations of each color-signal pair produce four intensity levels for each color—64 combinations.

When the Enhanced Display is operating in compatible low-resolution mode, it treats the color inputs as IRGB and ignores the two additional inputs. This allows the display to be used on the old adapters, and it allows the same palette set-up to display on either monitor in the compatible modes. But this removes the ability to display the additional colors in low-resolution modes. For this reason, the BIOS routines automatically switch to high resolution for the standard alphanumeric modes on the Enhanced Display—besides giving better looking text, the palette functions are fully available.

The palette operates all the time,

TABLE 3: *EGA BIOS RAM Usage*

LOC	NAME	SIZE	COMMENT
BASE	**SYSTEM BIOS**		
449	CRT_MODE	Byte	; Current BIOS mode
44A	CRT_COLS	Word	; Number of character columns
44C	CRT_LEN	Word	; Length of buffer in bytes
44E	CRT_START	Word	; Offset of current page
450	CURSOR_POSN	Word*8	; Cursor (col, row) for each of 8 pages
460	CURSOR_MODE	Word	; Current cursor mode setting
462	ACTIVE_PAGE	Byte	; Current page being displayed
463	ADDR_6845	Word	; Base I/O address for CRTC
465	CRT_MODE_SET	Byte	; Simulated value of CGA 3×8 register
466	CRT_PALETTE	Byte	; Simulated value of CGA 3×9 register
EGA	**BIOS**		
484	ROWS	Byte	; Number of character rows-1
485	POINTS	Word	; Bytes per character
487	INFO	Byte	; Miscellaneous info:
			; D7 High bit of mode (1 => no clear)
			; D6 Memory 00 = 64KB 01 = 128KB
			; D5 Memory 10 = 192KB 11 = 256KB
			; D4 Reserved
			; D3 0=EGA active, 1=EGA not active
			; D2 0=Write anytime
			; 1=Wait for display enable
			; D1 1=EGA has monochrome attached
			; D0 0=Emulate cursor type
			;
488	INFO_3	Byte	; Feature bits (D7-D4)
			; DIP switches (D3-D0)
4A8H	SAVE_PTR	Dword	; Points to table of pointers to save
			; areas
			; (see table 4 for layout)

This table shows some additional features of EGA's BIOS. Note especially the save area pointer that is located at 4A8H.

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even in monochrome modes. The monochrome display has only two inputs and three useful combinations, but the palette is still useful for achieving additional attribute/color combinations.

The attribute controller generates underlining whenever the background RGB bits are 000 and the foreground RGB bits are 001. By properly setting the palette registers for colors 0 and 1 (or 8 and 9), it is possible to get black characters on a white background with underlining. The original monochrome adapter could not do this.

The attribute controller has a couple of other neat tricks up its sleeve. Bit 3 of the attribute mode control register (3C0.10) enables blinking for characters where attribute bit 7 is set. This is similar to the function provided by bit 5 of register 3x8 in the old adapters. When blinking is enabled, attribute bit 7 is treated as a 0 for the purposes of background color selection, so the background choice is limited to one of eight colors. However, unlike the old adapters, the EGA palette can be set for any color combination for any index. This removes the restriction against mixing bright and dim background colors when blinking is enabled.

The monochrome graphics function supports 640 pixels by 350 lines on a high-resolution monochrome display. Bit planes 0 and 2 are used, both residing at segment A000H. Two bits, one for each plane, define each pixel as follows:

Plane 2	Plane 0	
0	0	Black
0	1	Video
1	0	Blinking video
1	1	Intensified video

Within each plane, the first byte defines the first eight pixels, the next byte the next eight, and so on sequentially for 28KB (640 pixels divided by 8 pixels per byte times 350 lines = 28,000 bytes). The high-order bit in each byte defines the first (leftmost) pixel, the low-order bit defines the last (rightmost). This is similar to the memory organization for the standard 640-by-200, one-color CGA mode, but there is no 8KB offset between even and odd scan lines. In monochrome graphics (as in all the new graphics modes) the memory organization is simply sequential.

The EGA has a feature that allows attribute bit 3 (normally the foreground intensity) to select an alternate character font table in the RAM character generator. This function is supported by BIOS, so it is not necessary to manipulate the hardware registers to achieve

TABLE 4: *BIOS Save Area Table Layout*

OFFSET	MEANING	
Dword 1	**Video Parameter Table Pointer** This pointer is initialized to BIOS EGA parameter table, and it must exist.	
Dword 2	**Dynamic Save Area Pointer** Initially 0000:0000, when nonzero this pointer is used to address a RAM area in which certain dynamic values are stored. For the Enhanced Graphics Adapter, the first 17 locations in the save area will contain the values of the 16 palette registers and the overscan color register. This save area must be at least 256 bytes long.	
Dword 3	**Alpha Mode Auxiliary Character Generator Pointer** Initially 0000:0000, when nonzero this points to a table with the following structure:	
	Byte	Bytes per character
	Byte	Char generator block to load (normally zero)
	Word	Number of character patterns to store (normally 256)
	Word	Character offset (normally 0)
	Dword	Pointer to a font table
	Byte	Displayable rows (FFH means display maximum possible)
	Byte	Consecutive bytes of mode values for which this font description is to be used, terminated with FFH.
Dword 4	**Graphics Mode Auxiliary Pointer** Initially 0000:0000, when nonzero this points to a table with the following structure:	
	Byte	Displayable rows
	Word	Bytes per character
	Dword	Pointer to a font table
	Byte	Consecutive bytes of mode values for which this font description is to be used, terminated with FFH.
Dword 5	Reserved, initially 0000:0000	
Dword 6	Reserved, initially 0000:0000	
Dword 7	Reserved, initially 0000:0000	
Dword 8	Reserved, initially 0000:0000	

The EGA BIOS's save area pointer points to various user-selected save areas in which BIOS stores the current values of additional parameters such as the palette registers. This allows programs to work with the current values used by BIOS.

TABLE 5: *Color Palette*

Palette register bit	7	6	5	4	3	2	1	0
Monochrome display	—	—	—	I	V	—	—	—
Standard color display	—	—	—	I	—	R	G	B
Enhanced color display	—	—	R′	G′	B′	R	G	B
Pin number in direct drive monitor connector			2*	6	7	3	4	5

** Pin 2 of direct drive monitor connector must be ground for standard color and IBM monochrome displays. Jumper P1 on the EGA selects R′ (1-2) or GND (2-3).*

The bits in the palette register are arranged as shown above for the three IBM monitors that can be used with the EGA. The last line of the table shows the corresponding pin positions on the direct drive monitor connector.

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the effect. Listing 4 illustrates how to set up this particular mode.

COMPATIBILITY ISSUES

The EGA is highly compatible with the earlier display adapters and associated software, as long as certain rules are obeyed. But what are the rules?

The most important one is "Render unto BIOS that which is BIOS's." Anything that BIOS can do, let it do. Even simple tasks, such as setting palette registers, ought to be done through BIOS if future compatability is important. A fundamental purpose of BIOS is to give hardware designers the freedom to implement old functions in new ways. The color palette is an excellent example. Though the color register at port 3D9 no longer exists, BIOS calls to select a palette or border color in the compatible modes are emulated by the EGA BIOS and turned into the proper palette register settings.

IBM has a stated policy that memory mappings (from the processor's viewpoint) will remain the same for any given BIOS mode number. This does not mean that all modes will live forever in all future hardware, but it does guarantee consistency among like-numbered modes in different environments. The alpha mode mapping of characters in the even bytes and attributes in the odd bytes will surely be with us for many years to come.

The flip side of this mapping policy is that identical display appearances may be produced by different modes and mapping. For example, the PC*jr* supports medium-resolution, 16-color graphics as mode 9 with two pixels per byte. The EGA achieves the same pixel and color resolution with mode D, but with eight pixels per byte in each of four parallel bit planes. Each mode uses the same amount of physical memory (32KB), but the EGA is more economical of address space, using only 8KB.

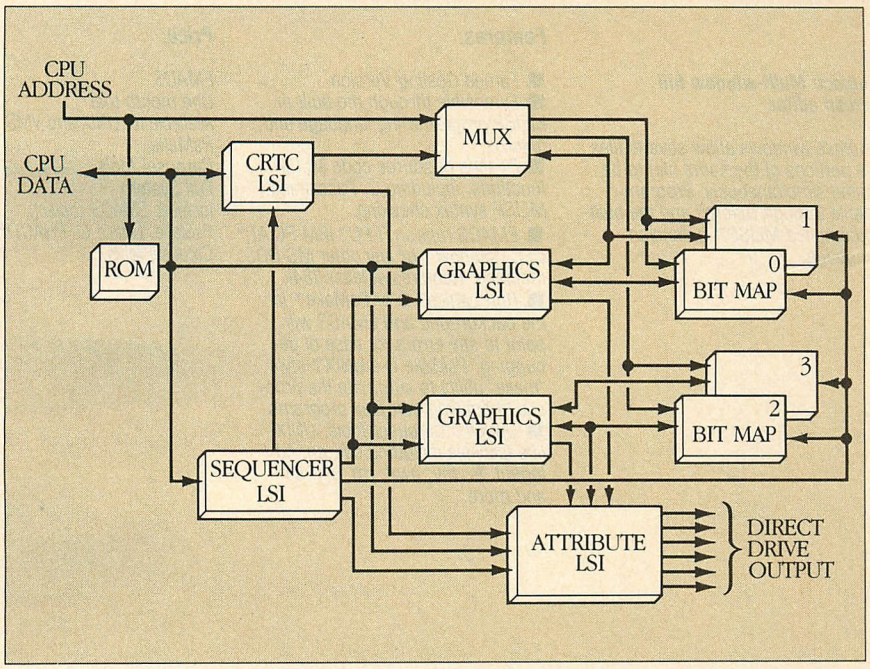
Besides the memory mapping for previously existing modes, the EGA makes some other concessions to compatibility. The light-pen hardware interface is identical, so programs that do not use BIOS to read the light pen should still work on the EGA. Also, the four low-order bits of the status register at 3xA have the same functions as in previous adapters, so programs that sense vertical or horizontal retrace can still work. It is no longer necessary to wait until retrace time to update the display memory without causing snow.

Existing software products were run on the EGA to test for compatibility at the highest possible level. The results were mixed.

BASIC 3.0 works correctly in all the compatible modes, but develops some odd characteristics in the new modes. In high-resolution color on the enhanced display, the cursor becomes a blinking *u* with an umlaut. This has been known to happen before when BASIC gets confused after switching display adapters from color to monochrome. In 43-line mode the cursor goes away completely, probably because BASIC initializes it to its own default values. BASIC thinks there are 25 lines, and it scrolls only the first part of the screen. The CLS statement gives four divide overflow messages, but Ctrl-Home clears the screen just fine. The BASIC graphics statements (LINE, CIRCLE, etc.) work only in the standard compatible modes.

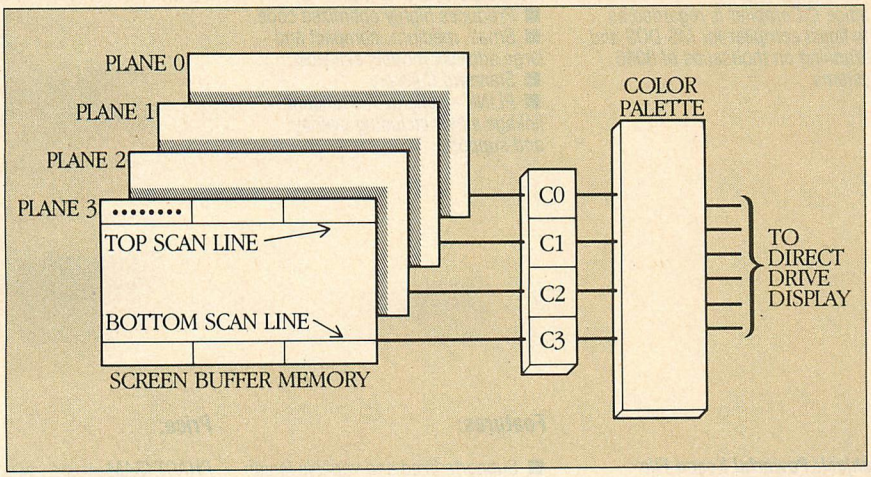
IBM has not announced, but we can still hope for, a version of BASIC that can make full use of new graphics

FIGURE 1: *Block Diagram of EGA*



The EGA has five custom large-scale integrated (LSI) circuits, reducing the chip count to 52 plus one crystal. The CGA, on the other hand, has 69 chips and no crystal, and the monochrome adapter has 66 chips and one crystal.

FIGURE 2: *Memory Organization for 16-color Graphics*



All planes are at the same processor address. Each plane is organized in the same manner: one bit per pixel, eight pixels per byte. Four bits (one from each plane) are combined in parallel to produce the color index into the palette registers. The output from the palette goes directly to the display monitor.

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modes. Perhaps this will come with next DOS release. A version of the BASIC Compiler that supports the same functions, plus the enhancements added in revisions 2.0 and 3.0, is overdue.

Microsoft Flight Simulator made the screen go bonkers, probably because it was trying to set up the hardware directly to allow centering of the picture. PC Paint from Mouse Systems worked well, but it apparently does direct output to port 3D9H to change the color palette. Since the EGA has no port 3D9H, the colors never change.

Since software does not come with a "We Followed the Rules" certification, and the rules may change, the user should try his most favored combinations before committing to purchase.

IBM already has announced some graphics software packages that support the EGA and other IBM display adapters as well as graphics printers and plotters (see table 7 for prices). The Graphics Development Toolkit provides a device-independent facility for graphics applications development. It includes a Virtual Device Interface (VDI), which provides the device independence, and device drivers for many different graphic input and output devices.

The VDI support for the EGA does not take full advantage of the colors available, nor is it especially fast (the demo program does not seem especially quick at fills, for example). The point of the VDI, however, is not speed but device independence. Programs using VDI do not even have to be recompiled for new graphics devices or modes: the drivers are implemented as DOS 2.1 loadable device drivers. Unlike the BIOS interface, the VDI interface is well specified, frozen, and oriented toward graphics applications. Applications developers should find this a very attractive way to insure compatibility with a variety of devices, present and future.

A Graphical File System, Graphical Kernel System, Plotting System, and Graphics Terminal Emulator are also available from IBM.

The Enhanced Graphics Adapter is a powerful device, made with state-of-the-art technology. It offers good performance, flexibility, and value. It is more capable than competing graphics cards, but a little more expensive (in comparable configurations), and a little less compatible with the original CGA.

Third-party hardware manufacturers are not likely to run out and start producing EGA clones. First of all, IBM has a big investment in the custom LSI chips that smaller independent companies would have a tough time matching.

TABLE 6: *Color Mixing*

	STANDARD					ENHANCED					
COLOR	I	–	R	G	B	R′	G′	B′	R	G	B
Black	0	0	0	0	0	0	0	0	0	0	0
Blue	0	0	0	0	1	0	0	0	0	0	1
Green	0	0	0	1	0	0	0	0	0	1	0
Cyan	0	0	0	1	1	0	0	0	0	1	1
Red	0	0	1	0	0	0	0	0	1	0	0
Magenta	0	0	1	0	1	0	0	0	1	0	1
Brown*	0	0	1	1	0	0	1	0	1	0	0
White	0	0	1	1	1	0	0	0	1	1	1
Dark gray	1	0	0	0	0	1	1	1	0	0	0
Light blue	1	0	0	0	1	1	1	1	0	0	1
Light green	1	0	0	1	0	1	1	1	0	1	0
Light cyan	1	0	0	1	1	1	1	1	0	1	1
Light red	1	0	1	0	0	1	1	1	1	0	0
Light magenta	1	0	1	0	1	1	1	1	1	0	1
Yellow	1	0	1	1	0	1	1	1	1	1	0
Intensified white	1	0	1	1	1	1	1	1	1	1	1

** Notice that in enhanced color mode, brown is composed of dark green and bright red.*

This table shows the palette register settings for the standard 16 IRGB colors in standard and enhanced color modes. When the PC is in the enhanced color mode, R'G'B' signals produce dim colors, RGB signals produce brighter colors, and a combination of the two produces the brightest colors.

TABLE 7: *Pricing and Related Products*

HARDWARE	
Basic EGA with 64KB	$524
Graphics Memory Expansion Card (64KB)	$199
Graphics Memory Module Kit (128KB)	$259
Fully loaded EGA with 256KB memory	$982
Enhanced Color Display	$849
Complete EGA System with 256KB and ECD	$1,831
SOFTWARE	
Graphics Development Toolkit	$350
Graphical File System	$175
Graphical Kernel System (GKS)	$295
Plotting System	$225
Graphics Terminal Emulator	$295

It costs more, but the EGA also offers more. Memory can be added in 64KB chips up to 256KB. IBM also has new graphics software for the EGA.

Second, the EGA is quite a bit more complex, and cloning will be a lot harder and take proportionately longer, by which time the clone may be obsolete.

The more likely course of events is for a continuing divergence of hardware implementations, supported by software interface standards such as the GKS, VDI, and even BIOS.

At $1,831 (see table 7), the complete package is expensive, mostly due to the cost of the Enhanced Color Display. Perhaps third-party display manufacturers will offer compatible displays for significantly lower cost, but even if they do not, the EGA has a lot to offer for users with standard color or monochrome displays.

Thomas Hoffmann is director of advanced systems development for General Instrument Corporation. He is a consulting editor whose last major article was a technical review of the PC/AT in the December 1984 issue.

SIDEBAR 1

EGA BIOS FUNCTIONS

EGA BIOS functions are accessed through interrupt 10H, with desired function code in AH, and other registers as detailed below.

AH = 0 Set mode
AL = mode (see table 2)
If bit 7 is set, video buffer will not be cleared (EGA only).

AH = 1 Set cursor mode
CH = start line for cursor (0 to 31)
CL = end line for cursor (0 to 31)

AH = 2 Set cursor position
BH = page number
DH,DL = row, column (0,0 is upper left)

AH = 3 Read cursor position
BH = page number
On exit:
DH,DL = row, column of current cursor
CH,CL = cursor mode currently set

AH = 4 Read light-pen position
On exit:
AH = 0: switch not closed, not triggered
AH = 1: valid light pen value in registers
DH,DL = row, column of LP character position
CH = raster line (0 to 199) in old graphics modes
CX = raster line (0 to nnn) in new graphics modes
BX = pixel column (0 to 319 or 639)

AH = 5 Select active display page
AL = new page value (see table 2 for max pages for each mode)

AH = 6 Scroll active page up (blank lines enter at bottom)

AH = 7 Scroll active page down (blank lines enter at top)
AL = number of lines (0 means entire window)
CH,CL = row,col of upper left corner
DH,DL = row, col of lower right corner
BH = attribute to be used on blank lines

CHARACTER HANDLING ROUTINES

For read/write character routines in CGA-compatible graphics modes (4, 5, and 6), the first 128-character code patterns are contained in system ROM, and the second 128-character code patterns are pointed to by the interrupt vector for INT 1F. The vector for INT 44 may be used to point to an alternate set of character patterns for character codes 0 to 127.

For the new graphics modes, 256-character patterns are supported in the system ROM, or through a pointer at the vector for INT 44.

AH = 8 Read attribute/character at current cursor position
BH = display page
On exit:
AL = character read
AH = attribute byte (alpha modes only)

AH = 9 Write attribute/character at current position
BH = display page
CX = count of characters to write
AL = character to write
BL = attribute (alpha) or color (graphics)
If bit 7 =1, character is XORed onto screen

AH = A Write character only at current cursor position
BH = display page
CX = count of characters to write
AL = character to write
In graphics modes, replication count in CX works correctly only if all characters written are contained on the same row.

GRAPHICS INTERFACE

AH = B Set color palette (for use in CGA-compatible modes)
BH = palette color ID being set (0 to 127)
0 = background color (0 to 15)
1 = palette combination
value 0 = green/red/brown,
value 1 = cyan/magenta/white
BL = color value to be used
In alpha modes, the value for color ID 0 sets the border color (0 to 31) where 16 to 31 select high-intensity background color.

AH = C Write dot
BH = display page
DX,CX = row, column
AL = color value (if bit 7 set, value is XORed with current value of dot)

AH = D Read dot
BH = display page
DX,CX = row, column
On exit:
AL = color value of dot read

MISCELLANEOUS FUNCTIONS

AH = E Write character to active page (TTY emulation)
AL = character to write
BL = foreground color in graphics mode

AH = F Return current video state
On exit:
AL = mode (see table 2)
AH = number of character columns on screen
BH = current active display page

AH= 10 Set palette registers
AL = 0: set individual register
BL = palette register number
BH = value to set
AL = 1: set overscan register
BH = value to set
AL = 2: set all palette registers and overscan
ES:DX points to 17-byte array (P0 to P15, then overscan)
AL = 3: toggle intensify/blinking bit
BL = 0: enable intensity
BL = 1: enable blink

AH = 11 Character generator functions

The following functions will cause a mode set, completely resetting the video environment, but without clearing the video buffer.

AL = 00: load user-specifid patterns

ES:BP = pointer to user table
CX = count of patterns to store
DX = character offset into map 2 block
BL = block to load (in map 2)
BH = number of bytes per character pattern

AL = 01: load ROM monochrome patterns (8 by 14)
BL = block to load

AL = 02: load ROM 8-by-8, double-dot patterns
BL = block to load

AL = 03: set block specifier
BL = block specifier
bits [3-2]: block for attr bit 3 = 1
bits [2-0]: block for attr bit 3 = 0
(Recommend calling INT 10 with AX=1000H and BX=0712H to set color plane enable register to ignore attribute bit 3 in addressing color palette registers.)

The following routines (AL=1x) are designed to be called only immediately after a mode set, and are similar to AL=0x except that:
Page 0 must be active
Bytes/character is recalculated
Max character rows is recalculated
CRT buffer length is recalculated
CRTC registers are reprogrammed
R09 = bytes/char-1 max scan line (mode 7 only)
R0A = bytes/char-2 cursor start
R0B = 0 cursor end
R12 vertical display end
= ((rows+1)*(bytes/char))-1
R14 = bytes/char underline loc
(*** BUG: should be 1 less ***)

AL = 10: user alpha load
ES:BP = pointer to user table
CX = count of patterns to store
DX = character offset into map 2 block
BL = block to load in map 2
BH = number of bytes per character

AL = 11: ROM monochrome set
BL = block to load

AL = 12: ROM 8-by-8 double-dot font
BL = block to load

The following functions are meant to be called only immediately after a mode set.

AL = 20: user 8-by-8 graphics characters (INT 1F)
ES:BP = pointer to user table

AL = 21: user graphics characters
ES:BP = pointer to user table
CX = bytes per character
BL = row specifier
0: user set—DL = number of rows
1: 14 rows
2: 25 rows
3: 43 rows

AL = 22: ROM 8-by-14 set
BL = row specifier

AL = 23: ROM 8-by-8 double dot
BL = row specifier
AL = 30: return information
BH = pointer specifier
0: INT 1F pointer
1: INT 44 pointer
2: ROM 8-by-14 character font pointer
3: ROM 8-by-8 double-dot font pointer
4: ROM 8-by-8 DD font (top half) pointer
5: ROM alpha alternate (9-by-14) pointer
On exit:
ES:BP = specified pointer value
CX = bytes/character
DL = character rows on screen

AH = 12 Alternate function select

BL = 10: return EGA information
BH = 0: color mode in effect (3Dx)
1: mono mode in effect (3Bx)
BL = memory installed
0: 64KB, 1: 128KB, 2: 192KB, 3: 256KB
CH = feature bits
CL = switch settings

BL = 20: select alternate print screen routine

AH = 13 Write string
CR, LF, backspace, and bell (07) are treated as commands, not printable characters.

ES:BP = pointer to string to be written
CX = character count
DH,DL = row, column position to begin writing
BH = page number
AL = 0:
string = (char, char, char, . . .)
BL = attribute
cursor is not moved
AL = 1:
string = (char, char, char, . . .)
BL = attribute
cursor is moved
AL = 2:
string = (char, attr, char, attr, . . .)
cursor is not moved
AL = 3:
string = (char, attr, char, attr, . . .)
cursor is moved

SIDEBAR 2

EGA I/O REGISTER SUMMARY

Register descriptions are presented in the format:
Port.Index Register name
[bit (s)] Function
Port.Index notation indicates that the address register for the device must first be written with the index value, then data can be read or written at the data register I/O address.

EXTERNAL REGISTERS

3C2 Miscellaneous output (write only)

[0]	Select base I/O address (0=3Bx, 1=3DX)
[1]	Enable RAM (1) / Disable RAM (0)
[2-3]	Dot clock select 00 = 14 mHz osc from I/O channel 01 = 16 mHz on-board osc 10 = external osc from feature 11 = not used
[4]	Select output source (0=internal, 1=feature output)
[5]	Page bit for odd/even mode (0=low, 1=high)
[6]	Horizontal retrace polarity (0=pos, 1=neg)
[7]	Vertical retrace polarity (0=pos, 1=neg)

3C2	Status 0 (read only)
[4]	Switch sense (switch addressed by dot clock select)
[5-6]	Feature code input
[7]	CRT interrupt (if enabled: 0=vert retrace, 1=display)

3xA	Feature control (write only)
[0-1]	FC0, FC1
[2-3]	Reserved

3xA	Status 1 (read only) Any input 3C0 to attribute address
[0]	Display enabled (1) / vert or horiz retrace (0)
[1]	Light-pen latch (0=armed, 1=triggered)
[2]	Light-pen switch (0=close, 1=open)
[3]	Vertical retrace (1) / display active (0)
[5-6]	Diagnostic video output monitor

3xB	Clear light-pen latch (write only)

3xC	Set light-pen latch (write only)

ATTRIBUTE CONTROLLER (write only)

The attribute address register at 3C0 points to the attribute data register where data are to be written. An internal flip-flop switches between address and data registers. The flip-flop may be cleared to address mode by reading input status 1 at I/O address 3xA.

3C0	Attribute address / palette address source
[0-4]	Attribute address
[5]	Palette address source (0=processor, 1=display memory) (Must be 0 to load palette registers, 1 to enable display)

3C0.00-0F	Palette registers 0 to F (write only)
[0]	Blue
[1]	Green
[2]	Red
[3]	Blue' / mono video
[4]	Green' / intensity
[5]	Red'

3C0.10	Mode control
[0]	Graphics (1) / alphanumeric (0)
[1]	Monochrome attributes (1) / color attributes (0)
[2]	Enable line graphics codes (1) / ninth dot background (0)
[3]	Enable blink (1) / attr-7 = background intensity (0)

3C0.11	Overscan color
[0-5]	Same as palette registers

3C0.12	Color plane enable
[0-3]	Enable C0-C3 to attribute controller (1)
[4-5]	Video status mux (to status1 [4-5]) 00 = R B 01 = B' G 10 = R' G' 11 = not used

3C0.13	Horizontal pixel panning
[0-3]	Number of pixels to shift video data left

SEQUENCER (write only)

3C4	Sequencer address

3C5.00	Reset (active low)
[0]	Async reset (0)
[1]	Sync reset (0)

3C5.01	Clocking mode
[0]	Dots per character (0=9, 1=8)
[1]	CRT bandwidth (0=high, 1=low)
[2]	Shift load (0=every character, 1=every second character)
[3]	Dot clock (0=normal, 1=halved)

3C5.02	Map mask
[0-3]	Enable CPU writes (1)

3C5.03	Character map select
[0-1]	Map B select (attr bit 3 = 0)
[2-3]	Map A select (attr bit 3 = 1) A and B must be different and extended memory installed to enable map select function for attr bit 3.

3C5.04	Memory mode
[0]	Alpha (1=enable char gen) / nonalpha (0)
[1]	Extended memory installed (1) / 64KB only (0)
[2]	Sequential addressing (1) / odd/even mode (0)

GRAPHICS CONTROLLER (write only)

3CC	Graphics 1 position (must be 00 for EGA)

3CA	Graphics 2 position (must be 01 for EGA)

3CE	Graphics 1 & 2 address

3CF.00	Set/reset
[0-3]	Values written to planes for which S/R is enabled when write mode is 0

3CF.01	Enable set/reset

3CF.02	Color compare
[0-3]	Color value for which read mode 1 returns a 1 in matching bit positions

3CF.03	Data rotate and function select for write mode 0
[0-2]	Rotate left count for write mode 0
[3-4]	Function select for write modes 0 and 2 00 = unmodified 01 = AND 10 = OR 11 = XOR

3CF.04	Read map select
[0-2]	Map number (encoded) for processor read mode 0

3CF.05	Mode register
[0-1]	Write mode 00 = rotate processor data, apply function, write planes enabled (S/R planes get 8 bits from S/R register bit for that plane)

	01 = write processor latch for each plane (loaded by previous read) 10 = each plane gets 8 bits of value of corresponding data bit 0-3 (fast color fill) 11 = not valid
[2]	Test condition (0=normal, 1=GRPHC outputs high impedance)
[3]	Read mode (0=selected plane, 1=color compare results)
[4]	Odd/even (1) (normally matches 3C5.04[2])
[5]	Shift even bits from even maps, odd from odd (1) This option implements CGA-compatible, four-color modes with two adjacent bits per pixel.
3CF.06	Miscellaneous
[0]	Graphics (1=disable char gen latches) / alpha (0)
[1]	Chain odd maps after even maps (1)
[2-3]	Memory mapping in processor address space 00 = A000 for 128KB 01 = A000 for 64KB—high-resolution graphics 10 = B000 for 32KB—monochrome alpha 11 = B800 for 32KB—CGA-compatible
3CF.07	Color don't care
[0-3]	Do not consider planes for which bits are set when doing color compare reads (read mode 1).
3CF.08	Bit mask
[0-7]	Bits set to 0 are protected from modification in all planes (that is, they are written from memory latches.) To preserve data, location must be read before writing.

CRT CONTROLLER (write only except where indicated)

Registers marked with an asterisk are new or different from corresponding registers in Motorola 6845 CRT Controller used in the IBM Monochrome Monitor Adapter and the IBM Color/Graphics Monitor Adapter.

3x4	Address
3x5.00	Horizontal total (total characters – 2)
3x5.01	Horizontal display end (total displayed-1)
*3x5.02	Start horizontal blank (character count)
*3x5.03	End horizontal blank
[0-4]	Start blank + blank width in chars –> 5 bits
[5-6]	Display enable skew (0-3 character times)
*3x5.04	Start horizontal retrace (character position)
*3x5.05	End horizontal retrace
*[0-4]	Start retrace + retrace width in chars —> 5 bits
*[5-6]	Horizontal retrace delay (0-3 character times)
*[7]	Start field on odd/even memory address—used for horizontal pixel panning (0=even, 1=odd)
*3x5.06	Vertical total (scan lines)
*3x5.07	Overflow (contains bit 8 for the following values)
*[0]	Vertical total (index 06)
*[1]	Vertical display enable end (index 12)
*[2]	Vertical retrace start (index 10)
*[3]	Start vertical blank (index 15)
*[4]	Line compare (index 18)
*[5]	Cursor location (index 0A)
*3x5.08	Preset row scan
*[0-4]	First scan line after vertical retrace (for vertical pixel panning)
3x5.09	Max scan line (0-31)
3x5.0A	Cursor start (scan line 0-31)
3x5.0B	Cursor end
[0-4]	Last scan line (0-31)
[5-6]	Cursor skew (0-3 characters)
3x5.0C	Start address high
3x5.0D	Start address low Together form a 16-bit word address (see 3x5.05[7])
3x5.0E	Cursor location high (read/write)
3x5.0F	Cursor location low (read/write)
3x5.10	Light pen high (read only)
3x5.11	Light pen low (read only)
*3x5.10	Vertical retrace start
*3x5.11	Vertical retrace end
*[0-3]	Start retrace + width of retrace in scan lines –> 4 bits
*[4]	Clear vertical interrupt (0=clear)
*[5]	Enable vertical interrupt (0=enable on IRQ2)
*3x5.12	Vertical display end (last scan line)
*3x5.13	Offset (additional offset in words to next logical line)
*3x5.14	Underline location (scan line 0-31)
*3x5.15	Start vertical blanking (scan line)
*3x5.16	End vertical blanking
*[0-4]	Start blank + blank width in scan lines –> 5 bits
*3x5.17	Mode control
*[0]	Compatibility mode (0=row scan A0 used for MA13 for 8KB offset between even and odd scan lines in CGA graphics modes)
*[1]	Select row scan counter (0=row scan A1 used for MA14)
*[2]	Horizontal retrace select (0=normal, 1=divide by 2 to double vertical resolution)
*[3]	Count by 2 (0=normal, 1=clock memory address with character clock / 2 for word refresh address)
*[4]	Output control (0=enable, 1=force high impedance)
*[5]	Address wrap for CGA compatibility in word address mode (0=MA13 to MA0 output, 1=MA15 to MA0 out). Use MA13 in odd/even mode with 64KB, MA15 with >64KB.
*[6]	Word address (0) / byte address (1) mode. In WAM, internal MA0-14 are output on MA1-15, and MA13 or MA15 (see 3x5.17[5]) on MA0.
*[7]	Hardware reset (0=reset, 1=normal operation)
*3x5.18	Line compare (scan line) When scan line counter reaches this value, internal MA is cleared to zero. Used for split screen.

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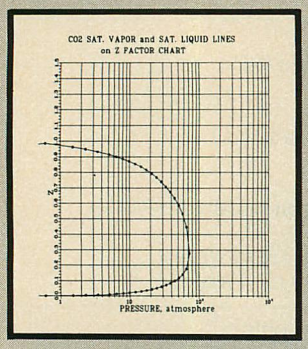
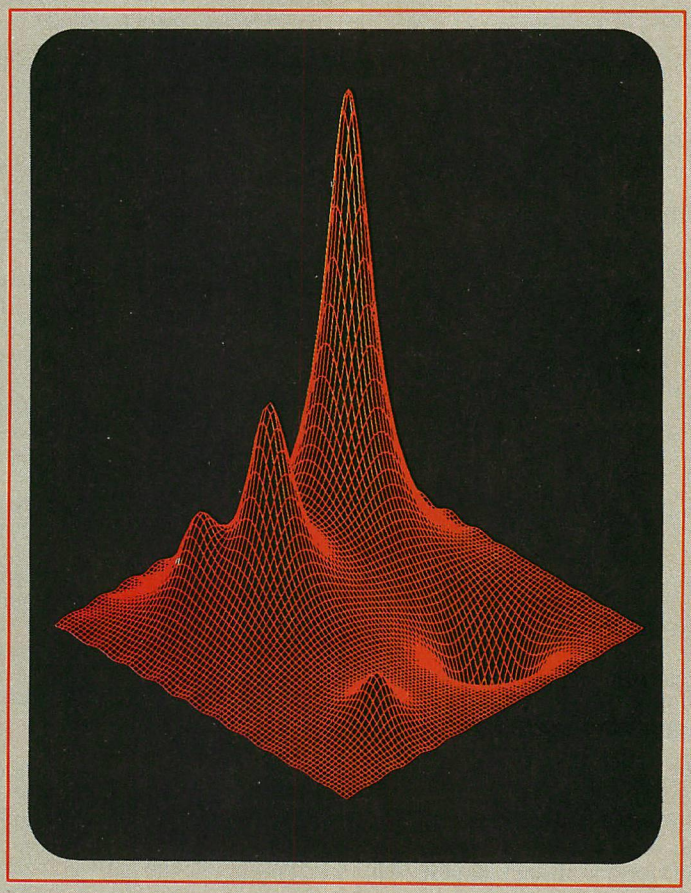
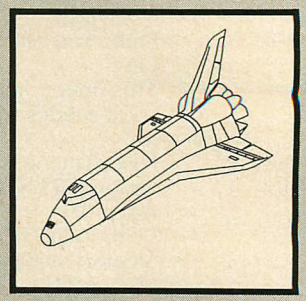


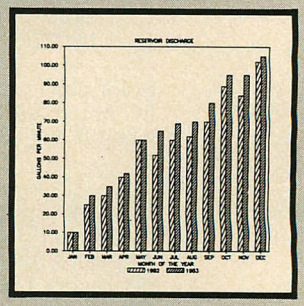
Scientific Plotting

Symbol Sets

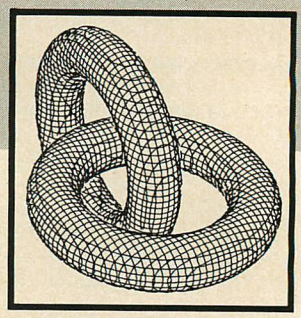




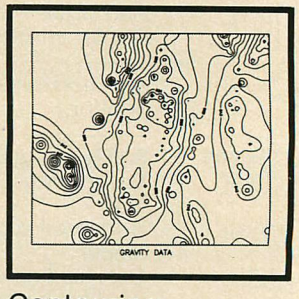
Digitizing



Business Graphics



Program Output



Contouring

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LISTING 1: SMALL.ASM

```
Page    60,132
Title   SMALL -- Load EGA 8x8 Font for 25 or 43 Line Screens
Subttl  Thomas V. Hoffmann, January 1985

;--This program selects 80x25 alpha color mode (mode 3), loads the
;  EGA character generator with the 8x8 font, and causes BIOS to
;  recalculate the video parameters for maximum screen dimensions.
;
;   With 350-line displays, this gives 43 lines per screen.
;   With 200-line displays, this gives 25 lines per screen.
;

Stack   segment para stack 'stack'
        dw      64 dup (0)
Stack   Ends

Bdata   segment at 40H          ;-- BIOS data segment
        org     63H
CRTC    dw      ?               ; Base I/O address of CRTC
        org     87H
info    db      ?               ; Bit 0=1 inhibits cursor emulation
Bdata   Ends

Code    segment para public 'code'
Small   proc    far
        Push    es              ; Push ES:0 for return to DOS
        Sub     ax,ax
        Push    ax
        Mov     ax,Bdata        ; Set DS to BIOS data segment
        Mov     ds,ax
        assume  ds:Bdata

        Mov     ax,0003H        ; Set 80-column alpha mode
        Int     10H

        Mov     ax,1112H        ; Load 8x8 font
        Mov     bl,0            ;   into block 0
        Int     10H             ;   and recalc screen

; This code sets the EGA CRTC cursor register directly, after
; inhibiting the BIOS cursor emulation function.  On 350-line
; displays, this prevents BIOS from setting the cursor to lines
; 11 and 12, which are not displayed for 8-line characters.

        Or      info,1          ; Inhibit cursor emulation
        Mov     ax,0100H        ; Set cursor
        Mov     bh,0            ;   for page 0
        Mov     cx,0600H        ;   to last two lines
        Int     10H             ;    (start on 6, off on 0)
page

; This code sets the underline location register in the CRTC to
; the last line of the character box (line 7).  BIOS incorrectly
; sets it to line 8, which is not displayed.

        Mov     dx,CRTC         ; Get CRTC base address
        Mov     al,14H          ; Select underline loc register
        Out     dx,al
        Inc     dx              ; Point DX to CRTC data register
        Mov     al,7            ; Set underline loc to line 7
        Out     dx,al

; This code enables the EGA BIOS print screen routine, which
; can handle non-standard display dimensions.  In this case
; it handles 43 lines of characters on 350-line displays.

        Mov     ax,1200H        ; Select EGA screen print
        Mov     bl,20H          ;   routine
        Int     10H

        Ret                     ; Return to DOS
Small   Endp
Code    Ends
        End
```

LISTING 2: GRAPH16.BAS

```
 1 '-- GRAPH16.BAS  16-Color Graphics Example
 3 '   This program is very slow, even when compiled.
 4 '   It is intended as an example only.
 5 '   The EGA must be the currently active display adapter.
25 '   Runs in Mode E (640 by 200, 16 colors)
30 '   Memory Map:  4 Planes at &HA000
40 '   8 Pixels per byte, non-interleaved
60 DEFINT A-Z
70 CLS
75 '-- The following line is for the compiled version only.
80 CALL SETMODE     '-- Set Mode after BASIC initialization
100 DEF SEG=&HA000 '-- Video buffer
110 INPUT "How many boxes? ", NBOXES
200 FOR BOX=1 TO NBOXES
210    X1=RND*639: Y1=RND*199
220    X2=RND*639: Y2=RND*199
230    C=RND*15
240    GOSUB 900
250 NEXT BOX
260 BEEP
270 WHILE INKEY$="": WEND
280 SYSTEM
900 '----------
901 ' Fill Box from (x1,y1)-(x2,y2) in color C
910 FOR X=X1 TO X2
920   FOR Y=Y1 TO Y2
930     GOSUB 1000
940   NEXT Y
950 NEXT X
960 RETURN
1001 '-- Put Pixel (color=C) at Location (X,Y)
1010 ROWBYTE = INT (X/8)
1020 BITMASK = 2 ^ (7 - (X MOD 8) )
1030 BYTEOFFSET = (Y * 80) + ROWBYTE
1040 ' Mask all but desired pixel position
1050 OUT &H3CE,8         '-- Graphics Bit Mask Register
1060 OUT &H3CF,BITMASK   '-- Mask all but desired pixel
1070 ' Read previous contents to latches (all maps)
1080 OUT &H3C4,2         '-- Sequencer Map Mask
1090 OUT &H3C5,&HFF      '-- Enable all 4 maps
1100 JUNK = PEEK (BYTEOFFSET)
1110 ' Blank the pixel
1120 POKE BYTEOFFSET,0
1130 ' Now set desired color in sequencer map mask
1140 OUT &H3C4,2         '-- Sequencer Map Mask
1150 OUT &H3C5,C         '-- Desired Color
1160 ' Write 1's to selected planes
1170 POKE BYTEOFFSET,&HFF
1180 RETURN
```

LISTING 3: SETMODE.ASM

```
     Page 60,132
Title     SETMODE -- Set Mode E for GRAPH16 BASIC example.

Subttl    Thomas V. Hoffmann, January 1985

Code segment   para public 'code'
     public    SetMode
SetMode   proc far

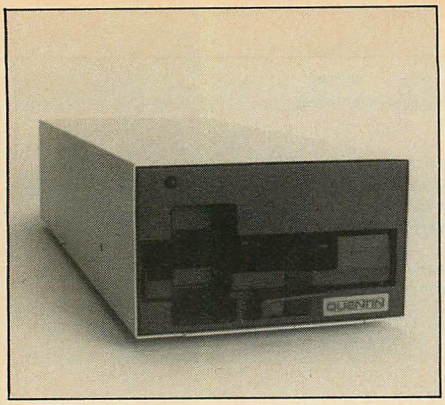
     Mov  ax,000EH  ; Set 320 by 200, 16 color mode
     Int  10H

     Ret            ; Return to BASIC

SetMode   Endp
Code Ends
     End
```

LISTING 4: DUALFONT.BAS

```
100 '-- Dual Font Example
110 COLOR 7,0: CLS
120 PRINT "EGA Dual Character Fonts"
130 PRINT
140 COLOR   4,0: PRINT "Font 0 is 7x9 in 8x14 box."
150 COLOR 8+4,0: PRINT "Font 1 is 5x7 in 8x8 box."
160 PRINT
170 COLOR   6,0: PRINT "Fonts can be ";
180 COLOR 8+6,0: PRINT              "mixed ";
190 COLOR   6,0: PRINT                    "on a line."
200 PRINT
210 COLOR   1,0: PRINT "Blue is underlined ";
220 COLOR 8+1,0: PRINT                    "in either font"
230 PRINT
240 COLOR   1,6: PRINT " but only on a black background. "
300 WHILE INKEY$="": WEND
310 WHILE INKEY$="": WEND
320 SYSTEM
```



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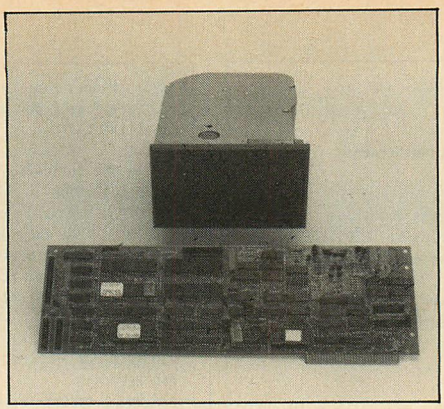

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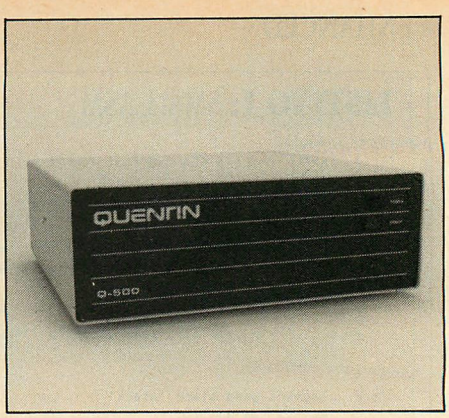

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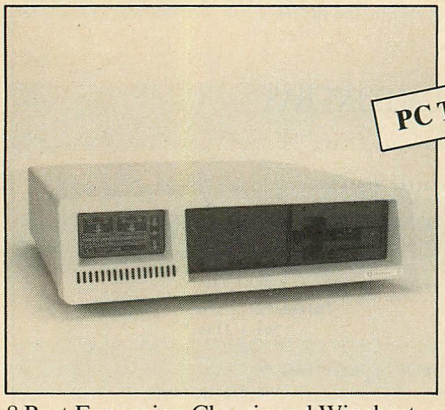

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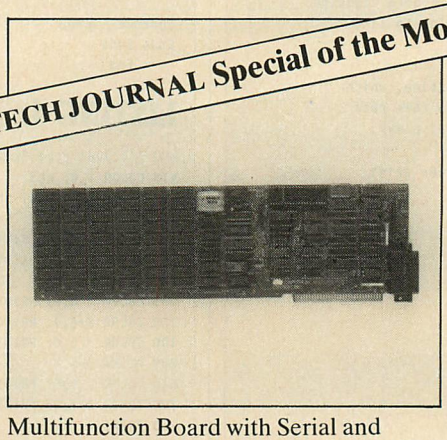

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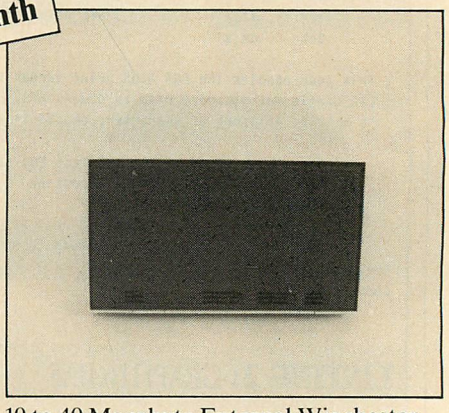

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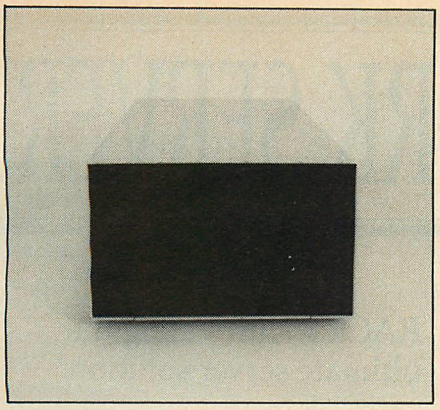

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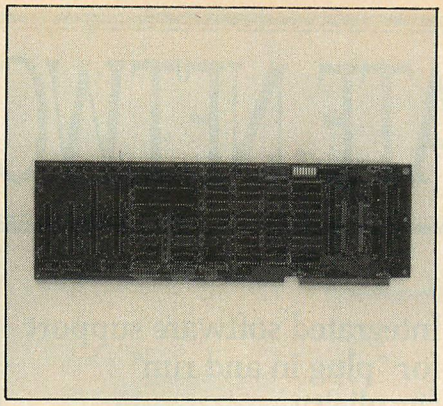

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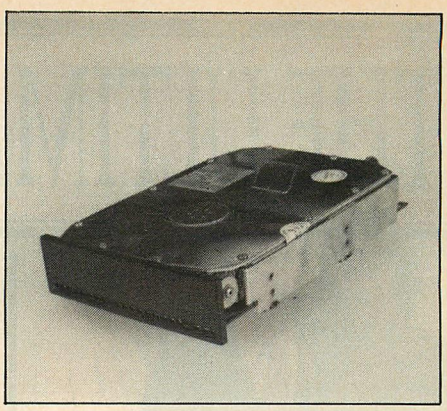

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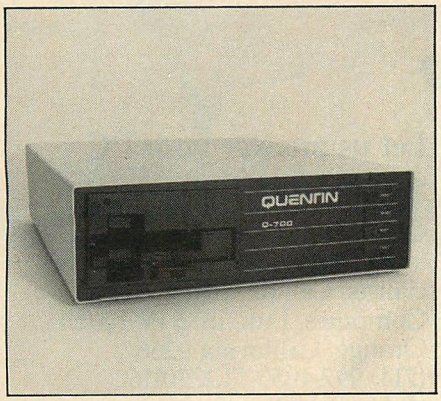

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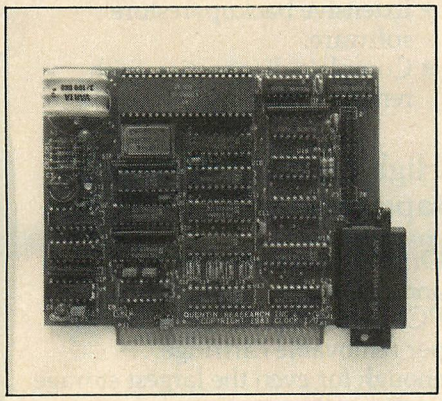

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Untangling Programs

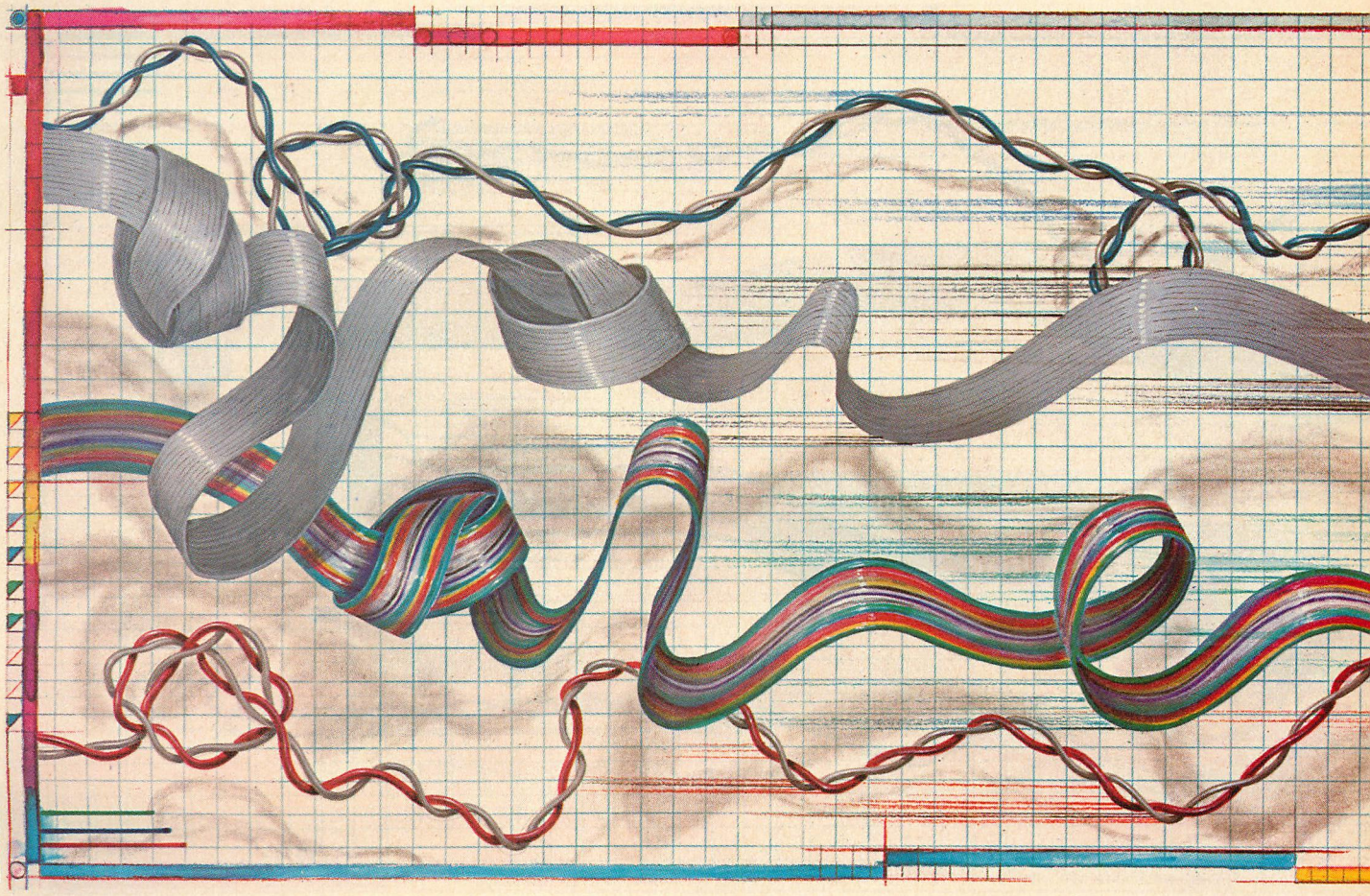
Two hardware-assisted debuggers with different orientations offer power and speed previously unavailable.

STEVEN ARMBRUST and TED FORGERON

Using most IBM PC debuggers can be a slow, hit-or-miss process requiring hours of painstaking search with little assurance of early success (or any success). Recently, however, a new breed of debugger has come on the scene that can really cut the programmer loose from the debugger bind in dramatic ways.

These new debuggers combine software with a board that fits into one of the PC's expansion slots and a probe into which the PC's 8088 microprocessor is plugged. Thus, they are termed *hardware-assisted* debuggers. Although they are relatively expensive, costing roughly $1,000 to $3,000, they provide debugging power that formerly was available only with in-circuit emulators costing in the $8,000 to $20,000 range. (See "Entomological Explorations," Steven Armbrust and Ted Forgeron, *PC Tech Journal*, January 1985, p. 88 for an overview of 19 different debuggers.)

This article compares two hardware-assisted debuggers: PC PROBE, by ATRON, and PDT-PC (Program Develop-



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ment Tool for the PC) by Answer Software Corporation. PC PROBE was highlighted previously in the May 1984 issue ("It's PC PROBE!" Thomas V. Hoffmann, p. 86). As the initial review revealed, it provides all the tools a systems programmer needs to debug complicated operating system and device-driver code. PDT-PC, on the other hand, lacks some of the features of PC PROBE, but its lightning speed makes debugging large applications programs a breeze.

First things first. Any PC product that costs over $1,000 must provide special features unavailable anywhere else. Hardware-assisted debuggers do just that. They have all the standard features of a simple debugger, like PC-DOS's DEBUG, but they perform feats of debugging magic that answer many a programmer's dreams. For example, hardware-assisted debuggers support hardware breakpoints without affecting the speed of the program running. This can save hours in unraveling programs with many complicated execution paths, and it can help detect bugs that are timing-related and not evident in the usual slowed-down debugging environment.

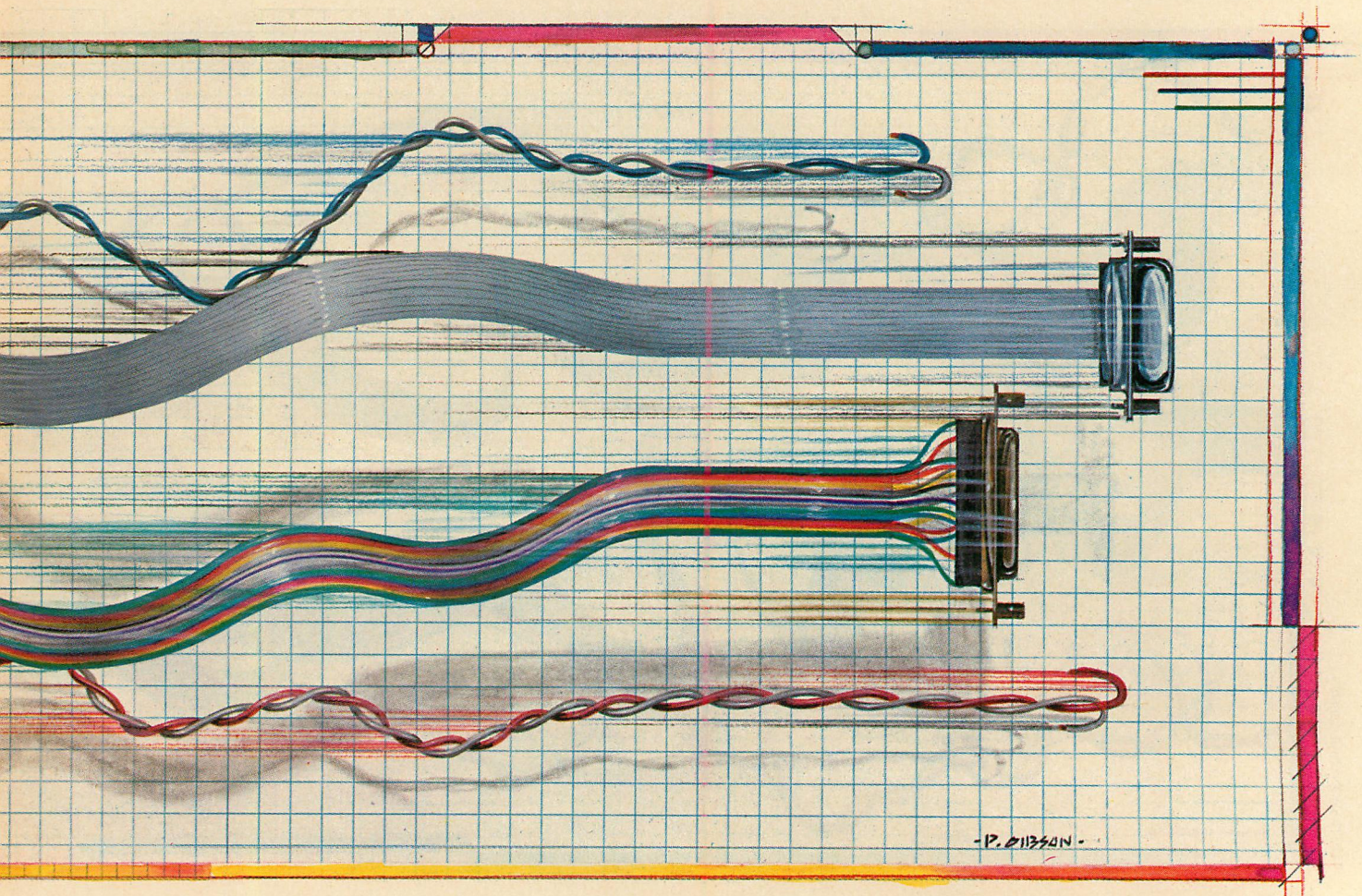
Hardware-assisted debuggers can also accumulate a list of previously executed instructions (a program trace) while the program is executing at full speed. A trace displays the instructions leading up to a breakpoint or program crash, enabling the programmer to analyze the problem. This is probably the most important advantage that hardware-assisted debuggers have over conventional software-only debuggers.

Hardware-assisted debuggers can also accumulate a list of previously executed instructions (a program trace) while the program is executing at full speed.

Another way in which hardware-assisted debuggers excel is in their ability to recover from program crashes. Program crashes present difficulties for software-only debuggers, because the crash often renders the keyboard useless, making it impossible to access the debugger. The only way to regain control is to reboot, but that clears memory and destroys the evidence of the crash. Hardware-assisted debuggers solve this problem by including reset switches that allow the system to be reset in the event of a program crash. When a program crash happens, a simple press of the reset switch will regain control of the microprocessor, a command is entered to access the debugger, and the instructions executed just prior to the crash can be examined.

Performance analysis is another area helped by hardware-assisted debuggers. Special software can check programs to see which modules execute most often and which execute for the longest times. Armed with this information, a program's performance can be improved by redesigning and recoding the bottleneck areas. PC PROBE also provides its own protected memory. This feature prevents an out-of-control program from overwriting the debugger's code and data areas.

It is the hardware that makes all of these features possible. No software-only debugger can perform these kinds of functions and still allow programs to execute at normal speeds. And some of



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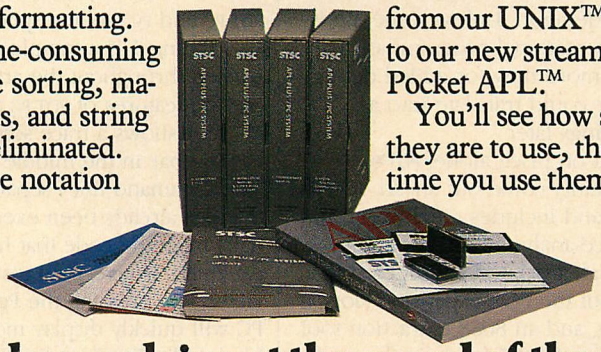

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these features, like hardware breakpoints, are simply not possible without some form of hardware assistance.

Familiar companies like AT&T, IBM, Intel, Microsoft, and Lotus already use hardware-assisted debuggers in their programming departments, as do many smaller and less familiar software companies. These companies find that even though hardware-assisted debuggers are more expensive than other less powerful debuggers, they save time and money, and they provide the features (hardware breakpoints, realtime back trace, program crash recovery, and performance monitoring) that professional programmers need.

These extra—and sometimes essential—features allow programmers to debug and tune their code faster. A debugger like this pays for itself in no time if it can help a $3,000-a-month programmer find an elusive bug in one hour instead of in one week. To carry the process a step further, if programmers can debug programs faster, their companies can bring products to market sooner. The sooner products are on the market, the sooner they can start bringing in revenue, and so on.

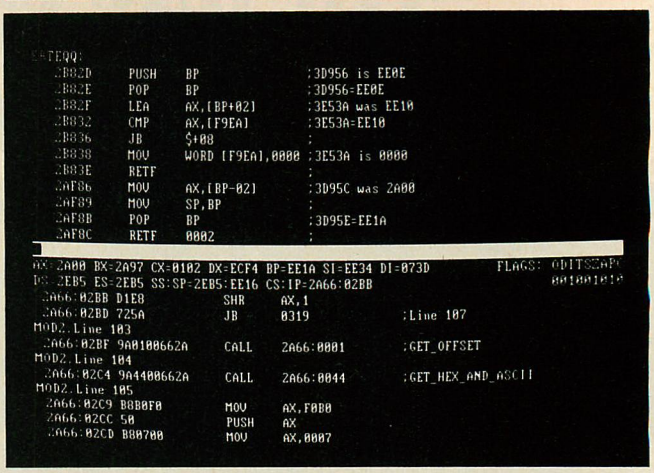
Both PC PROBE and PDT-PC are used at Multisoft Corporation, which considers returning to debugging techniques such as inserting diagnostic WRITE statements or using tools like IBM DEBUG to be "primitive." In particular, this company believes that, like any other craftspersons, programmers need high-quality, precision tools to get their jobs done quickly and correctly. Multisoft programmers have found that hardware-assisted debuggers like PDT-PC and PC PROBE reduce debugging time to less than half of what it took the "old way."

Obviously, any programmer would love to have the power of a hardware-assisted debugger at his disposal, but their relatively high price tags put them out of reach for some. Still, the high cost alone should not eliminate them from consideration. Unless someone is strictly a recreational programmer, paying a little more now for added debugging power could translate into a greater savings later.

Judged on price alone, PDT-PC would certainly come out ahead. It sells for $1,775 and includes a debugger and performance-analysis diskette, a reference manual, a printed circuit card that fits in one of the PC's expansion slots, a probe plug, and an 8088 extraction tool. PC PROBE costs $2,495 for a similar package, with the addition of an external reset switch, but its performance-analysis software is not included in the base price (it is an additional $395).

The hardware and installation for both PDT-PC and PC PROBE were similar. A circuit board is popped into any available slot in the PC. The 8088 is removed from its socket on the motherboard and inserted into a carriage that is connected to a ribbon cable. The carriage is then plugged into the vacated socket, and the cable is attached to the circuit board. This procedure is easier said than done; the pins on both carriages are extremely fragile and any attempts to gently urge an errant member back into line can result in a clean, but fatal, fracture.

PHOTO 1: *PDT-PC Trace Screen*



The bar in the middle is the command line. Above the bar is executed code. Instructions below it are not yet executed. At the bottom are public symbols and source line numbers.

The difference in ease of use between PDT-PC and PC PROBE is like the difference between using the IBM Personal Editor and PC-DOS's Edlin: PDT-PC is screen-oriented like Personal Editor, and PC PROBE is line-oriented like Edlin. With PC PROBE, specific commands are entered to view the backtrace of already-executed code or the disassembly of yet-to-be executed code. The following command displays a backtrace of the previous 20 instructions:

```
TRACE 20
```

The user repeats the command to see 20 more lines of backtrace.

PDT-PC, on the other hand, lets the user move through the code with extreme speed. Instead of specific commands, the cursor keys and the PgUp and PgDn keys are used for navigation. Tables 3 and 4 list the commands for PDT-PC and PC PROBE respectively.

Listing 1 is a sample program that is used throughout the article to example the features of PDT-PC and PC PROBE. Photo 1 shows a trace screen from PDT-PC. The bar in the middle of the screen (the command line) separates the code that has already been executed (the top half) from the code that has yet to be executed. Unexecuted instructions are viewed by pressing the PgDn key: PDT-PC will quickly display more disassembled code. To move backwards through the disassembled code (or through the backtrace in the top half of the screen), press PgUp.

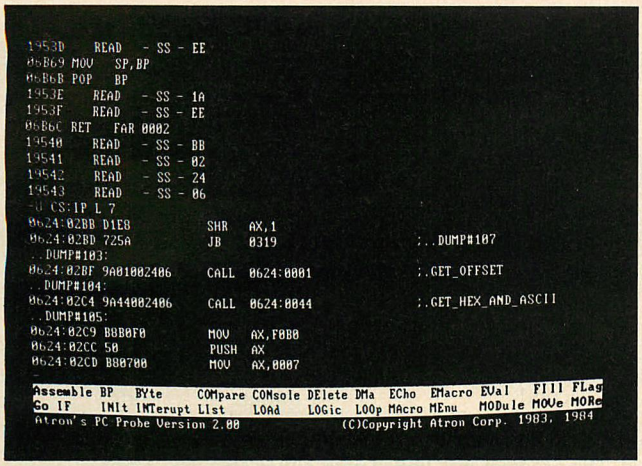
Photo 2 shows the same information displayed by PC PROBE. To display this information, the user enters two commands: a TRACE command to display a backtrace of the previous few lines of code, and an UNASSEMBLE command to display disassembled code. PC PROBE provides a more detailed display of backtrace information than PDT-PC.

If PLINK86 is used to link object modules (see "Program Orchestration," Steven Armbrust and Ted Forgeron, *PC Tech Journal,* November 1984, p. 28, for a review of this linker), and the SYMTABLE option is used, the executable code file (.EXE file) generated by PLINK86 will contain information about a program's public symbols. Both debuggers can access this information, but it is easier and faster with PDT-PC.

The difference between PDT-PC and PC PROBE is like the difference between IBM's Personal Editor and PC-DOS's Edlin: PDT-PC is screen-oriented like Personal Editor, and PC PROBE is line-oriented like Edlin.

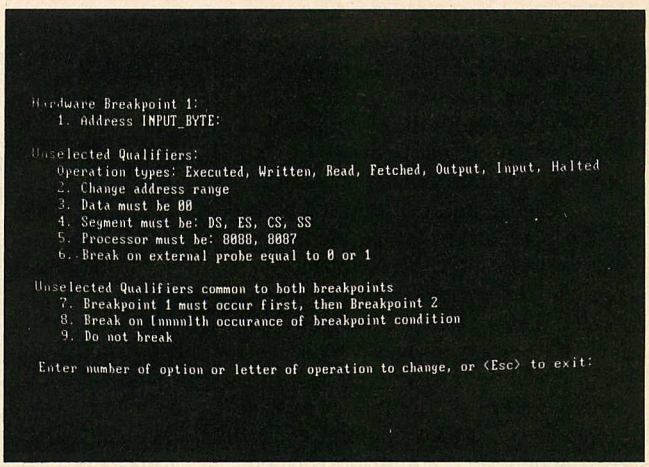
PDT-PC has a special command that allows the .EXE files generated by PLINK86 to be loaded into memory in one step. PDT-PC is smart enough to read

PHOTO 2: *PC PROBE Trace Screen*



Public symbols are displayed on the right. The bottom of the display shows the available commands. PC PROBE provides a more detailed display of backtrace information than PDT-PC.

PHOTO 3: *PDT-PC Hardware Breakpoint*



From this full-screen menu, the user types the appropriate number (1-9) or the first letter of the desired operation (E, W, R, F, O, I, or H) to set information about the breakpoint.

the symbol addresses from the .EXE file instead of forcing a separate map file to be loaded. So, in one trial, loading a 270KB program linked with PLINK86 (complete with public symbols) took only 52 seconds with PDT-PC.

PC PROBE, on the other hand, requires a PLINK86-generated .EXE file to be run through a separate utility. This utility builds a Microsoft-compatible link map that the debugger must digest to provide support for symbols. This means that a program linked with PLINK86 must be loaded with the link map, even though PLINK86 includes the symbol table in the .EXE file itself.

Even with this utility, PC PROBE cannot handle programs containing many public symbols, because of its limited symbol storage space. Loading the same 270KB program linked with PLINK86 (complete with public symbols) first required five and one half minutes for the utility to generate a map file that PC PROBE could digest. Then, PC PROBE stopped loading after 91 seconds because it ran out of symbol space.

Photo 1 shows how PDT-PC displays public symbols. In the lower part of the screen are two CALL instructions. On the right side, prefaced by semicolons, are the names GET_OFFSET and GET_HEX_AND_ASCII. These procedures are about to the called. (Listing 1 shows the source code for these procedures.) Without this symbol information, the program's link map would have to be scrutinized to determine which procedures were being called. Photo 2 shows the same public symbols displayed by PC PROBE.

PDT-PC also includes another tasty feature that helps to debug code linked with PLINK86: it allows breakpoints to be set at symbols that reside in overlaid parts of the program. It is not necessary to wait for the overlay to be loaded into memory before setting a breakpoint on a symbol residing in that overlay. Instead, the breakpoint can be set at anytime, and PDT-PC will keep track of its as-yet-undetermined address.

This is important for PLINK86 users who write large, overlaid programs (one of the strengths of PLINK86 is its support for overlays). The only other debugger on the market to support this feature is the software-only debugger PFIX86-PLUS, developed by the creators of PLINK86.

In the area of debugger protection, PC PROBE wins hands down. It has 128KB of write-protected memory that stores the debugger software, the symbol table, and the macro tables. This protected memory prevents program bugs from changing memory locations used by the debugger itself. Conversely, PDT-PC stores all of its symbol information in the PC's normal, unprotected RAM.

Protected memory is a nice feature, but this 128KB of protected RAM is one of the reasons that PC PROBE costs almost 40 percent more than PDT-PC. Also, the requirement that a program's symbols must be located in protected RAM limits the number of symbols usable during a debugging session, which may prevent PC PROBE from being used to debug extremely large programs. (This limitation was evidenced in the loading of the 270KB test program.)

Because PDT-PC stores its symbol information and the debugger itself in the PC's unprotected RAM, it is susceptible to bugs that indiscriminately write over memory locations. However, if extra room is required for symbol storage, more memory can be added to the PC; PDT-PC's Y command can be used to increase the size of the symbol table.

If speed is the issue, PDT-PC is one of fastest debuggers around, both in loading code and in the retrieval and display of information. It is faster, by far, than PC PROBE. The benchmarks in tables 1 and 2 compare the performance of the two using the program in listing 1. A diskette-based system was used to run all benchmarks. Commands were written down on paper first to reduce "think time" as a factor in performance; typing was done at a normal speed. Each benchmark was done four times—the results shown are averages.

Both debuggers allow macro definitions that can be saved in a file, but PDT-PC's macro capabilities are inferior to those of PC PROBE. PC PROBE can nest macro calls and call macros recursively. PDT-PC allows no nesting or recursion. PC PROBE allows its macros to pass up to 10 parameters. PDT-PC does not allow parameters in macros.

PC PROBE supports an initialization macro (called INITIALIZE), the contents of which are user-definable. When PC PROBE is loaded, it automatically searches for the INITIALIZE macro in a file called INIT.MAC and executes it. PDT-PC has no such feature. A powerful macro facility is important because it allows personalization of the debugger through the creation of custom commands. To some extent, PC PROBE's powerful macros compensate for the inefficiencies in its command syntax.

The INITIALIZE macro that was used with PC PROBE when debugging the sample program (dump.pas) is shown

in figure 1. Because a macro is automatically invoked each time PC PROBE is invoked, it saves the user from having to remember all the things he ordinarily would have to do when starting a PC PROBE debugging session.

Both debuggers allow two kinds of breakpoints to be set: hardware breakpoints and software breakpoints. The main difference between the two here is in the approach to setting the breakpoints. PC PROBE uses the command approach—a separate command must be entered every time a breakpoint is set. PC PROBE's power gives it so many breakpoint options that it is difficult to remember them all, but it does provide a help window at the bottom of the screen. Whenever a command is typed, PC PROBE dynamically updates a command window that displays the options.

With PDT-PC, options for complicated breakpoint commands are selected from a full-screen menu. More cumbersome than the command approach, but it does present all breakpoint options at once. Photo 3 shows an example of the menu used to set up hardware breakpoints with PDT-PC. To set information about the breakpoint, the appropriate number (1 through 9) or the first letter of the operation (Written, Executed, Read, Fetched, Output, Input, or Halted) is entered. In this example, 1 was typed and the name of a public variable (INPUT_BYTE) was entered; W was typed to indicate that a breakpoint should occur when information is *written* to that location. One disadvantage to this approach is that the menus are difficult to use from macros.

Both debuggers are lacking in 8087 support. Each can disassemble 8087 instructions, and PDT-PC can assemble them as well. But neither can display real number variables in a readable form, nor can they help change real number variables on the fly.

PDT-PC supports two-monitor configurations (one each for the applications program's display and the debugger). For systems that have a single monitor, PDT-PC can save the application screen so that the programmer can switch between it and the debugger's screen. PC PROBE offers the same features, as well as an integrated RS-232 port and a serial interface driver. The PC PROBE debugger screen can thus be viewed on a separate CRT. For the programmer who would like to take a peek at his source code in the middle of a debugging session, PDT-PC answers the call: it allows the viewing of another file during the session. PC PROBE does not offer this flexibility feature.

TABLE 1: *Performance Benchmarks*

	PDT-PC	PC PROBE
MS-LINK		
Commands	PDTPC DUMP.EXE [enter]	PROBE [enter] LOA DUMP.EXE [enter] LOA S DUMP.MAP [enter]
Time	22 seconds	48 seconds
PLINK86		
Commands	PDTPC PDUMP.EXE [enter]	STRIPPE / [enter] PDUMP [enter] [enter] STRIP31.PAS [enter] PROBE [enter] LOA PDUMP.EXE [enter] LOA S PDUMP.MP1 [enter]
Time	15 seconds	1 minute 32 seconds

The commands required to invoke PDT-PC and PC PROBE and the program in listing 1 are compared. The program was linked with either MS-LINK 2.4 or PLINK86 1.43. In the case of MS-LINK, the benchmarks measure the time to load the debugger software, DUMP.EXE and DUMP.MAP, complete with symbols and line numbers. In the case of PLINK86, the SYMTABLE option was used to store the symbol and line numbers in the .EXE file itself.

TABLE 2: *Sample Debugging Session*

	PDT-PC	PC PROBE
a. Load debugger software, DUMP.EXE and DUMP.MAP	a. PDTPC DUMP.EXE TEST.IN TEST.OUT [enter]	a. PROBE [enter] LOA DUMP.EXE [enter] LOA S DUMP.MAP [enter]
b. Set and hit execution breakpoint at GET__OFFSET	b. GGET__OFFSET [enter]	b. G .GET__OFFSET [enter] TEST.IN [enter] TEST.OUT [enter]
c. Single-step three instructions	c. S S S	c. ST [enter] [enter] [enter] [space]
d. Disassemble 10 instructions	d. Nothing required	d. U L 10 [enter]
e. Set and hit breakpoint at GET__HEX__AND__ ASCII	e. GGET__HEX__AND__ ASCII [enter]	e. G .GET__HEX__AND__ ASCII [enter]
f. Display last 20 instructions in trace buffer	f. [PgUp]	f. T 20 [enter]
g. Exit back to DOS	g. Q [enter]	g. Q [enter]
Time	49 seconds	1 minute 48 seconds

This table exhibits the PDT-PC/PC PROBE comparisons for time and keystrokes in a sample debugging session, from initially loading the debugger to exiting to DOS.

Both debuggers offer performance analysis software that aids in determining which parts of a program are executed most-frequently and which are executed least-frequently—to find the places where performance could be improved by recoding in assembly language. This software is included with PDT-PC; it is extra with PC PROBE.

Another matter for consideration is whether having a software-only version of these debuggers makes sense. In a group of two or more software developers with a limited equipment budget, it probably would. Not every software engineer in a department may need all this power all the time; but it is helpful for everyone to have debugging tools that use the same command syntax.

Generally, only one out of every three or four members of a programming team really needs the power of a full hardware-assisted debugger. The rest can manage with a software-only

TABLE 3: *PDT-PC Commands*

COMMAND	DESCRIPTION
[F1]	Display help screen
[F2]	Display trace display
[F3]	Display breakpoint display
[F4]	Display user screen
[F5]	View user screen
[F7]	Perform analysis
A	Assemble to memory
B	Set/reset temporary breakpoints
C	Compare memory
D	Display memory bytes
DW	Display memory words
DP	Display memory pointers
E	Enter bytes into memory
EW	Enter words into memory
EP	Enter pointers into memory
F	Find string in memory
G	Go until breakpoint
H	Evaluate expression
I	Input byte from port
IW	Input word from port
J	Jump to address or symbol
LO	Load Intel and PLINK86 files
LM	Load MS-LINK files
M	Move memory
NA	Add macro
ND	Display macro list index
NI	Index macro list
N1	Load macros from file
NR	Remove macro
NW	Write macros to file
O	Output byte to port
OW	Output word to port
P	Set/reset permanent breakpoint
Q	Quit and return to DOS
S	Single step
T	Step and restore user screen
UE	Enter command parameters
UD	Display command parameters
UP	Display PDT internal parameters
V	Load view file
W	Write memory to file
X	Change register value
XF	Set or clear 8088 flags
Y	Allocate memory
ZA	Add symbol
ZD	Display symbols
ZI	Display module list index
ZO	Load symbol table
ZM	Load symbol table from map file
ZR	Remove symbol
ZS	Display symbol table size

PDT-PC has a special command, LO, that allows the .EXE files generated by PLINK86 to be loaded into memory in one step. Options for complicated breakpoint commands appear on a full-screen menu; all breakpoint options are shown at once.

TABLE 4: *PC PROBE Commands*

COMMAND	DESCRIPTION
ASSEMBLE	Assemble to memory
BREAKPOINT	Define or display sticky breakpoints
BYTE	Display or change bytes in memory
COMPARE	Compare contents of two blocks of memory
CONSOLE	Select local or remote console
DELETE	Delete symbols, macros, or breakpoints
DMA	Include DMA cycles in trace display
ECHO	Enable or disable screen display of macros
EVALUATE	Evaluate an expression or pointer
FILL	Fill range of memory locations
FLAGS	Display CPU flags
GO	Execute program until breakpoint
IF	Conditional execution of macro commands
INITIALIZE	Restore initial conditions
INTERRUPT	Enable or disable interrupts
LIST	List all PC PROBE output to file or device
LOAD	Load programs, symbols, or macros
LOGIC	Change heading for logic signals in trace display
LOOP	Loop within a macro
MACRO	Create a macro
MENU	Enable or disable a menu window
MODULE	Assign module name to symbols
MORE	Display next set of menu choices
MOVE	Move a block of memory
NEST	Display calling sequence of procedures
NOBREAK	Disable nonexecution break conditions
NOVERIFY	Disable read after write verification
PORT	Display or modify contents of an I/O port
PRINT	Print information to console
POINTER	Display or change 32-bit pointers in memory
QUIT	Leave PC PROBE and return to operating system
REGISTERS	Display or save CPU registers
SAVE	Save blocks of memory or macros in a file
SCREEN	Enable or disable screen switching
SEARCH	Search a block of memory
STEP	Single step
SYMBOL	Define a symbol
TRACE	Display backtrace
UNASSEMBLE	Unassemble range of memory
WINDOW	Open a window and display data
WORD	Display or change words in memory

PC PROBE's macro capabilities are superior to those of PDT-PC. PC PROBE can nest macro calls and call macros recursively; it allows its macros to pass up to 10 parameters. PDT-PC offers none of these advanced macro capabilities.

equivalent, with the hardware-assisted version nearby in cases of need (a good way to cut down on overall costs). PC PROBE is available in a software-only version called SOFTWARE PROBE (also from ATRON), which sells for $295 and includes a proper subset of the features found in PC PROBE.

Answer Software Corporation does not offer a software-only version of its product. However, Genesis Microsystems, the company that originally developed the PDT-PC software for Answer, sells a software-only version of PDT-PC called GeneScope, for $995.

Both companies offer excellent technical support and are quite receptive to user input. ATRON includes four hours of customer technical support with each PC PROBE (additional technical support time can be purchased). It also maintains a set of technical reports that describe how to use PC PROBE to debug applications that require complete control over the PC's hardware. According to ATRON, PC PROBE is warranted for 90 days, and the company promises to supply software bug fixes, free of charge, for a period of one year. In addition to this service, ATRON publishes bug reports outlining problems that customers have discovered with PC PROBE that have not yet been fixed.

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Answer Software states that PDT-PC is warranted for 90 days and that it will supply software updates, free of charge, for one year. And while its manual makes no specific mention of customer technical support, Answer provides such support easily, and has been known to incorporate customer-suggested feature enhancements and bug fixes into later releases of PDT-PC software.

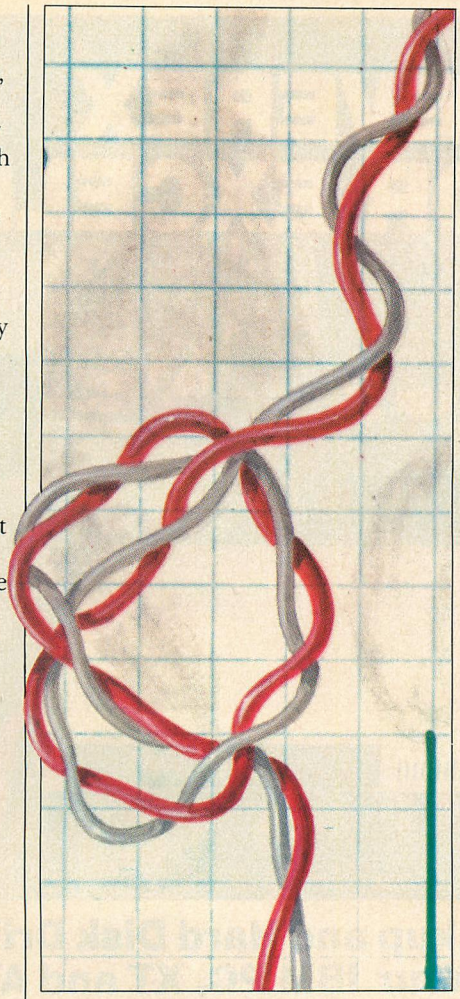
Both reference manuals are disappointing. The PC PROBE manual is slightly better, but neither company put forth much effort to produce quality documentation. Neither includes an index, which is an unforgivable shortcut.

The PC PROBE reference manual pages were produced by a near-letter-quality, dot-matrix printer. For $2,500, it is reasonable to expect a typeset manual. The manual does, however, provide detailed instructions on how to install the PC PROBE, and includes a sample debugging session to help acquaint the new user with the debugger's commands. Also, the command reference chapter is laid out in an easy-to-use format, in alphabetical order, with one command per page, and corner tabs that flag the command for that page.

Still, the manual is confusing because of another apparent cost-cutting maneuver: the same manual is used for four variants of PC PROBE, including PC PROBE itself, SOFTWARE PROBE, SOURCE PROBE, and SOFTWARE SOURCE PROBE. Extracting the information that applies to any one of these debuggers is trying, considering the name similarities.

Like ATRON, Answer also seemed to cut questionable corners on its manual. The PDT-PC manual was produced on a letter-quality printer and then photocopied. While this produced readable pages, there are twice as many as there perhaps should be, because the pages were photocopied on one side only. Also, the eight hand-drawn pictures in the installation section look as though they have been photocopied several times. The information about how to install and use PDT-PC is included somewhere in the manual, but it is difficult to say where as Answer did not list page numbers in the table of contents, nor do the pages have corner tabs.

In addition, a critical piece of information is missing from the PDT-PC manual. If a system does not have an 8087 installed, but the switch on the system board is set to indicate an 8087 is present, PDT-PC will not work. This switch-setting mistake is a common one; it is caused by the fact that many of the early IBM manuals documented the settings for this switch incorrectly. Needless to say, this simple problem can cause considerable time delays if the user is unaware of it.



Answer sells a demo diskette for PDT-PC for $20. It is a good way to become familiar with the product's features before purchasing the actual debugger. ATRON does not have a demo diskette for PC PROBE, but the company sometimes allows potential customers to try out PC PROBE and return it within 30 days for a full refund if it does not suit their needs. (The company indicates that the only returns have been from customers who tried using PC PROBE on custom hardware that only remotely resembled the IBM PC.)

Support for the PC/AT is an important feature for serious programmers who want to take advantage of the AT's speed in compiling and linking their programs. Both Answer and ATRON plan to introduce hardware-assisted debuggers for the AT in the near future.

ATRON, however, is taking a fast track in AT support. The company has already announced, and started shipping, a version of its SOFTWARE PROBE (not PC PROBE) that supports the PC/AT. With this debugger, instead of replacing the microprocessor with a probe (as with SOFTWARE PROBE on the PC), ATRON provides a board that plugs into one of the AT's short slots. The trade-off for taking up a board slot is that it averts the user from having to handle the very delicate 80286 chip.

Answer Software is taking a wait-and-see approach regarding the AT. It wants to create a product that supports the full capabilities of the AT, including support for 3MB of memory and protected mode on the 80286 microprocessor. Answer will probably wait until XENIX is available before releasing an AT version of PDT-PC.

No doubt, PDT-PC's features are powerful enough to make most programmers drool. Even so, there is room for improvement. For one thing, Answer could add the complete macro support that PC PROBE provides: an initialization macro and macro parameters would be useful additions. It would also be nice if PDT-PC allowed the hardware trace to be routed to a file or to the printer. Currently, it can only be viewed on the debugger screen.

Real number support would also improve PDT-PC. Users of floating-point numbers would benefit from being able to display and change the contents of

FIGURE 1: *Sample INITIALIZE Macro*

MACRO=INITIALIZE	(names the macro)
LOAD DUMP.EXE	(loads the program)
LOAD SYMBOLS DUMP.MAP	(loads the program's symbols from the map file)
SYMBOL .START=CS:IP	(defines a symbol .START as the program's start address)
REG	(displays the initial values of all registers)
UNASSEMBLE	(unassemble the first few lines of code)
END	(end of the macro)

This INITIALIZE macro was used with PC PROBE in debugging dump.pas (listing 1). The contents of this macro are user-definable; it is put in a file called INT.MAC.

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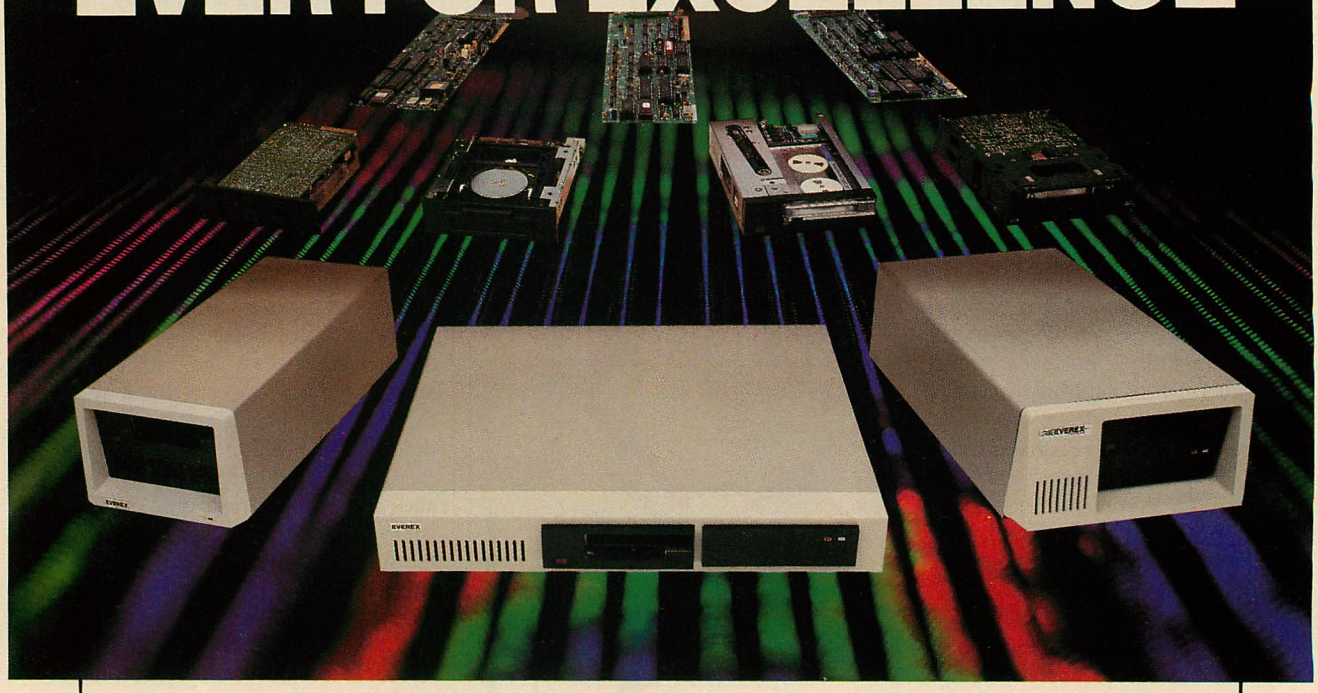

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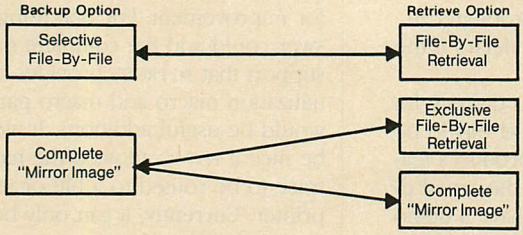

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REAL variables using a more readable representation. PDT-PC should add support for the IEEE standard that covers 8087 single- and double-precision formats, and it also should support the Microsoft format.

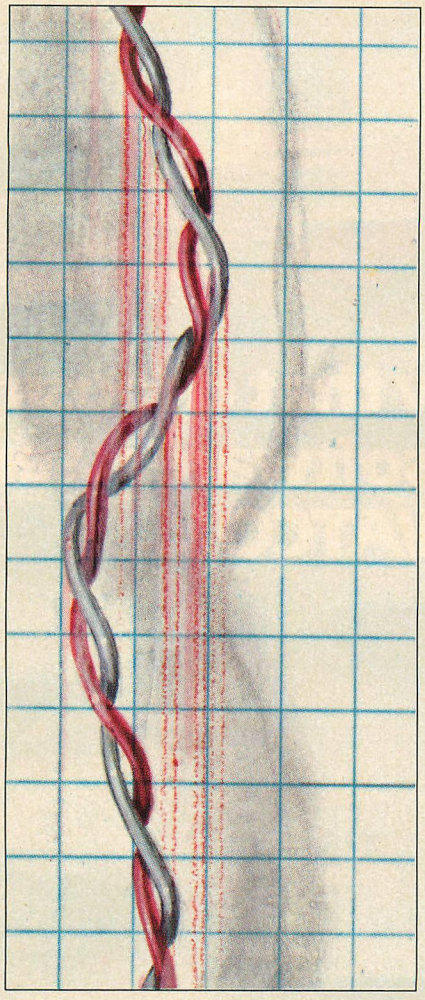
PDT-PC should provide an easier way to save a patched program to disk. Currently, a program can be patched in memory and the W command used to save the file. But the start address and the length of the file must be specified before it can be saved. In another area, the addition of a repeat count to some of the PDT-PC commands would save keystrokes. Although a few commands do support repeat counts, it would be nice, for example, to enter 10S to perform 10 single steps instead of having to enter the S command 10 times.

PDT-PC does include an interrupt switch that allows the programmer to access the debugger without rebooting. But the switch resides on the board bracket connected to the back of the computer, so interrupting the machine involves groping around in back to locate this tiny switch. Bringing that switch to the front of the computer for easy access would be an improvement (this is how PC PROBE is situated). PDT-PC also would be improved by the addition of a reset switch (like PC PROBE has) to reset the computer without rebooting.

Finally, the issue of bugs. Prior to version 2, the PDT-PC software had a number of bugs. (We have been PDT-PC users since version 1 and we have discovered six on our own.) None of the problems were critical, but some did limit the debugger's usability. Since most software developers are practical enough to realize that nearly every product is going to have a few bugs, the question that is most important is how eager the manufacturer is to fix problems once they have been identified.

Answer has shown that it is quite willing to listen to problems, and to swat bugs almost immediately. Each of the six problems reported, except one, has been fixed in a subsequent release of PDT-PC. And actually, the exception (that was not fixed) lies in that gray area between bug and feature: under certain circumstances, PDT-PC dramatically shrinks the size of the hardware backtrace it displays (the history of the instructions the program executed before encountering a breakpoint).

This happens as follows: PDT-PC maintains two trace buffers. One, a command trace, maintains a history of commands invoked by the user; the other, the hardware trace, shows the history of program instructions executed. When a PDT-PC command is typed after hitting a breakpoint, the debugger transfers the last 10 lines of the hardware trace to the command trace. Then it displays the command trace on the screen and no longer shows the complete hardware trace. The trace disappears only if a command is typed. Otherwise, the complete hardware trace can be viewed by using the cursor keys or the PgUp and PgDn keys.



PC PROBE really shines for debugging systems software development, such as operating systems, boot loaders, networking software, and I/O device drivers.

This situation causes problems because a programmer might wish to enter a command while studying the hardware trace. For example, he may want to display the contents of a variable or look at the program's stack. But as soon as he does, most of the hardware trace disappears, with no chance for retrieval.

A compromise solution to this problem would be to add an option to the debugger that allows the user to choose which trace (the command trace or the hardware trace), is to be preserved and displayed following a breakpoint. An alternative compromise would be to add the capability to print the hardware trace (or save it to disk) for later reference. As yet, Answer has not implemented either of these fixes/features.

Like PDT-PC, PC PROBE is an extremely powerful debugger, but also like PDT-PC, PC PROBE could benefit from some improvements. First, PC PROBE stores all the information about a program's symbols in a fixed area of reserved memory on the debugger board. Even though this memory is protected from misbehaving programs, there is not enough of it. Debugging large programs almost always causes the debugger to run out of symbol space. PC PROBE should provide an option to reserve part of the PC's memory for symbols, even though that memory is unprotected. At the least this option would allow programmers to examine large programs, if they were willing to give up the safety of protected memory.

Another area in which PC PROBE could improve is its support for PLINK86 files. To access the symbols generated by PLINK86, PC PROBE requires the .EXE file to be run through a separate utility. This takes extra time and requires the user to keep track of two separate files for each program: the .EXE file and the map file produced by the utility. Instead, PC PROBE should read the symbols directly from the .EXE file.

PC PROBE would also be better if it had a feature (as PDT-PC does) that allows users to refer to symbols that exist in overlays, even if those overlays are not yet loaded into memory. Finally, PC PROBE has the same deficiency that PDT-PC has in supporting real numbers: both should display those numbers in a more readable form.

It is not appropriate to ask which debugger is "better"—to ask that would be like asking which high-level language is better for programming, C or Pascal. The answer is that each is good in its own way, but each is better suited to solve a different kind of problem.

PC PROBE really shines for debugging systems software development, such as operating systems, boot loaders, networking software, and I/O device drivers. ATRON even includes specific

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sections in its reference manual that describe how to debug boot load sequences and installable device drivers.

Also, PC PROBE works best when debugging system-level routines because it provides the programmer with every conceivable piece of information about the code being debugged. And even though it is significantly slower than PDT-PC, speed is not as important with system-level routines because most are relatively small. (For example, the resident part of a classic piece of systems code, DOS 2.0, is only 24KB.)

In addition, PC PROBE's support for an external console is a godsend when debugging system-level routines that take over the keyboard. The external console can be used to enter all the debugging commands directly to PC PROBE and thereby avoid reentrancy problems with the keyboard interrupt handler on the PC. Having the debugger reside in protected RAM also helps when debugging low-level system problems that take pot shots at any memory location.

PDT-PC can be used for systems software development, but its forte is in debugging applications software where speed is important. Instead of debugging small pieces of systems code, an applications software developer might have to debug 256KB of code or more in a relatively short amount of time. In this environment, debugging tools must be fast, and PDT-PC is the fastest.

Tools like PDT-PC and PC PROBE are relatively expensive; but, they can save a great deal of time. They are easy to learn and use. For the systems programmer, we strongly suggest a closer look at PC PROBE. For the applications programmer, pick up the phone and order PDT-PC. Either way, there will be no regrets in using a debugger that really lets the user pull the strings.

PDT-PC version 2.2: $1,775
Answer Software Corporation
20863 Stevens Creek Blvd., B2-C
Cupertino, CA 95014
408/253-7515
CIRCLE 447 ON READER SERVICE CARD

PC PROBE version 2.0: $2,495
SOFTWARE PROBE: $295
ATRON
20665 Fourth Street
Saratoga, CA 95070
408/741-5900
CIRCLE 499 ON READER SERVICE CARD

Steven Armbrust is a senior documentation engineer and Ted Forgeron is vice president of systems software engineering at Multisoft Corporation in Beaverton, Oregon.

LISTING 1: dump.pas

```
{$title:'HEXIDECIMAL DUMP PROGRAM'}
{*************************************************************}
{                                                             }
{ Create a hexidecimal dump of any file and output it to the  }
{ output file or device of your choice.                       }
{                                                             }
{       To output a hex dump of GLORP.XYZ to a file named     }
{       GLORP.DMP you should type:                            }
{               DUMP GLORP.XYZ GLORP.DMP                      }
{                                                             }
{       To output a hex dump of GLORP.XYZ to your monitor you }
{       should type:                                          }
{               DUMP GLORP.XYZ CON:                           }
{                                                             }
{       To output a hex dump of GLORP.XYZ to your printer you }
{       should type:                                          }
{               DUMP GLORP.XYZ LPT1:                          }
{                                                             }
{*************************************************************}
{$list-}
{$include:'finkxm'}                     ! FCB declarations
{$list+}

PROGRAM dump(input_file,output_file) ;

  USES filkqq ;                         ! FCB declarations

  CONST
    file_bytes_per_line = 16 ;
    hex_bytes = (3*file_bytes_per_line) + 2 ;

  TYPE
    ascii_chars = SET OF char ;         ! all 256 characters

  VAR
    input_file [PUBLIC] : FILE OF byte ;
    output_file [PUBLIC] : text ;
    ascii_set [PUBLIC] : ascii_chars ;
    offset [PUBLIC] : word ;
    offset_string [PUBLIC] : lstring(7) ;
    hex_string [PUBLIC] : lstring(hex_bytes) ;
    ascii_string [PUBLIC] : lstring(file_bytes_per_line) ;
    status [PUBLIC] : boolean ;
{*************************************************************}

  PROCEDURE get_offset [PUBLIC] ;

    BEGIN
      status := encode(offset_string,offset:4:16) ;
      offset := offset + file_bytes_per_line ;
      concat(offset_string,'  ') ;
    END ;
{*************************************************************}
```

```
  PROCEDURE get_hex_and_ascii [PUBLIC] ;

    VAR
      i [PUBLIC] : integer ;
      scratch [PUBLIC] : lstring(2) ;
      input_byte [PUBLIC] : byte ;
      input_char [PUBLIC] : char ;

    BEGIN
      hex_string := null ;
      ascii_string := null ;
      FOR i := 1 TO file_bytes_per_line DO
        BEGIN
          input_byte := input_file^ ;
          status := encode(scratch,input_byte:2:16) ;
          concat(hex_string,scratch) ;
          concat(hex_string,' ') ;
          input_char := chr(input_byte) ;
          IF input_char IN ascii_set
            THEN
              concat(ascii_string,input_char)
          ELSE
              concat(ascii_string,'.') ;
          get(input_file) ;
          IF eof(input_file)
            THEN
              BREAK ;
        END ;
      IF hex_string.len < hex_bytes
        THEN
        FOR i := ord(hex_string.len) + 1 TO hex_bytes DO
          concat(hex_string,' ') ;
    END ;
{*************************************************************}

  BEGIN                                 ! dump main program
    offset := 0 ;
    offset_string := null ;
    ascii_set := [' '..'~'] ;           ! only 1st 126 ascii chars
    reset(input_file) ;
    rewrite(output_file) ;
    writeln(output_file) ;
    writeln(output_file,'Hexidecimal Dump of File: ',
            input_file.name) ;
    writeln(output_file) ;
    writeln(output_file,'OFFSET':-25,'HEX':-37,'ASCII') ;
    writeln(output_file) ;
    WHILE ( NOT eof(input_file)) DO
      BEGIN
        get_offset ;                    ! collect offset part
        get_hex_and_ascii ;             ! collect hex & ascii parts
        writeln(output_file,offset_string,hex_string,ascii_string) ;
      END ;
  END.
```

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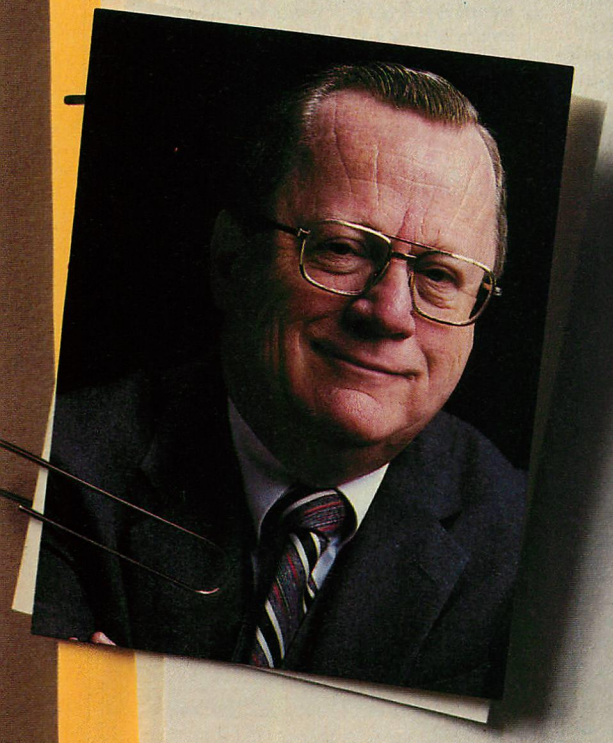

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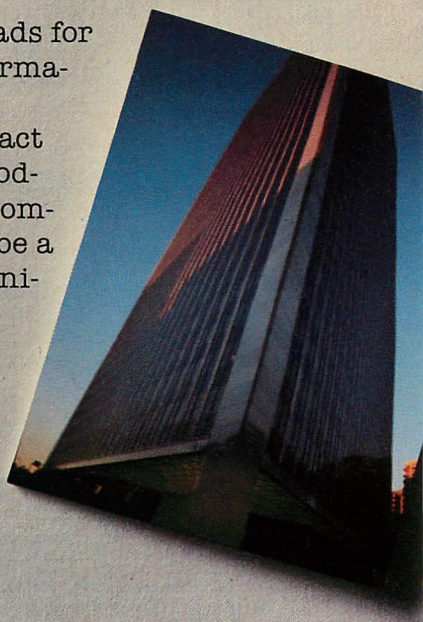

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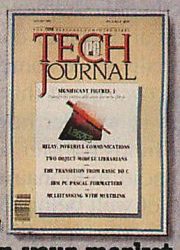

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Encryption Methods

Enhancing data security on the PC

VICTOR MANSFIELD

This is the first part of a two-part article about encryption and the IBM PC. The second part, to appear next month, will discuss the Data Encryption Standard and the Public Key Cryptography system.

Having just finished writing an elegant new program using your micro, you send it to your software publisher via electronic mail. With his micro he receives the program and transfers the promised million dollars into your bank account. Flushed with that feeling of well-being that only millionaires know, you leave your computer, allowing some other humble programmer to use the machine.

A few minutes after you leave the office, some doubts begin to invade your euphoric state. How do you know that one of your vicious competitors did not intercept the program during transmission? After all, national computer networks are exceedingly complex, and there are many ways an intruder could wiretap them, especially since some of the links are by microwaves. At this point you also begin to wonder how secure that electronic funds transfer was.

Like other paranoid millionaires, you feel your sense of well-being diminish rapidly as you consider all the possible ways your wealth could be stolen. You begin to wonder if that programmer with whom you share the micro might maliciously modify the copies of your precious program residing on the hard disk. After all, he is a pretty good systems programmer, so the password protection offered by the operating system will present no serious obstacle to him. He might even steal your program and claim that it is his.

The problems of communications security and controlled sharing of files can be at least partly solved through encryption, a technique for controlling access to information by disguising it. Although the basic techniques of encryption are more than 2,000 years old, they are as relevant today as they were then, particularly as a means to enhance security in the burgeoning field of computers and communications.

Methods of encryption have undergone tremendous development since the days when the early Greeks and Egyptians used primitive ways of coding to protect their important military and diplomatic information. In addition, the need for such encryption has spread far beyond the military and diplomatic areas. With the enormous increase in the use of electronic equipment to transfer funds and to handle sensitive data, ranging from future marketing plans and designs for new products to personnel records, the commercial need for encryption is large and widespread. The potential danger of industrial espionage has also fueled the interest in all forms of computer security.

Surprisingly, the largest commercial user of encryption is the satellite TV industry, which employs it to prevent nonsubscribers from receiving free programs. Another potential application for

ILLUSTRATION • GARY ZAMCHICK/LEXICA

BUYERS GUIDE TO DESKTOP ORGANIZERS

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	PolyWindows Desk	Sidekick	Spotlight
ROLODEX-TYPE FILES			
Variable Card Size	**YES**	NO Files	NO
Multiple Card Decks	**YES** (1-10)	NO Files	**YES**
Number Cards Per Deck	**RAM Limit**	NO Files	500 Max.
Max. Characters Per Card	**969**	NO Files	480
Search	**YES**	NO Files	**YES**
Auto Alphabetize	**YES**	NO Files	**YES**
Print Card	**YES**	NO Files	**YES**
Print Deck	**YES**	NO Files	**YES**
CALENDAR			
Daily Notes	**YES**	NO	NO
Mark Important Days	**YES**	NO	NO
Date Range	**1752-2099**	1901-2099	1901-2099
APPOINTMENT BOOKS			
Multiple Appt. Books	**YES** (1-10)	NO	NO
"Things To Do" List	**YES**	NO	NO
Print Appointment Book	**YES**	**YES**	**YES**
ALARM CLOCK			
Display Time	**YES**	NO Alarms	**YES**
Hourly Chimes	**YES**/Optional	NO Alarms	NO
Time Format	**AM / PM**	NO Alarms	AM / PM
Display Alarm Message	**YES**	NO Alarms	NO
Number of Alarms	**9**	NO Alarms	Many
CALCULATOR			
On-Screen Tape	**YES**/Optional	NO	NO
Printing Tape	**YES**/Optional	NO	NO
Percentage Function	**YES**	NO	**YES**
Display With Commas	**YES**/Optional	NO	NO
Floating/Fixed Decimals	**YES/Both**	Fixed	Floating
Memory	**YES**	**YES**	**YES**
Insert Result in Work	**YES**	**YES**	**YES**
Max. Display Digits	**15**	18	12
Display Number > Above	**YES/Exponential**	NO	NO
Scientific Notation	**YES**	NO	NO
Binary/Hexadecimal	NO	**YES**	NO
NOTEPAD			
Multiple Documents	**YES** (1-10)	NO	NO
Word Wrap	**YES**	NO	**YES**
Merge Files	**YES**	NO	NO
Change Margins	**YES**	NO	NO
Variable File Size	**YES**	**YES**	NO
File Size Limit	**64K**	50K	4.4K
Variable Window Size	**YES**	**YES**	NO
Print Document	**YES**	**YES**	**YES**
Print Window Only	**YES**	**YES**	**YES**
Undelete Key(s)	**YES**	**YES**	NO
Cut & Paste Screen Text	NO (Note 1)	Import Only	NO
KEYBOARD ENHANCER			
Number Keys Redefined	**YES Up to 60**	NO/Not Avail.	NO/Not Avail.
Total Keystrokes	**YES** 2500	NO/Not Avail.	NO/Not Avail.
GENERAL CHARACTERISTICS			
100% Memory Resident	**YES**	NO	NO
Minimum Memory Used	**47,500**	61,300	77,200
Typical Memory Used	**50-75K**	61,000	77,200
On-Line Help	**YES**	**YES**	**YES**
Moveable Windows	**YES**	**YES**	NO
Redefine Colors	**YES**	**YES**	**YES**
Expandable/Add Functions	**YES**	NO	NO
Can Remove Functions	**YES**	NO	NO
Integrated Interface	**Excellent**	Good	Good
Visual Appeal	**Excellent**	Fair	Poor
Speed	**Very Fast**	Fast	Slow
ADD-ON FUNCTIONS			
Auto Dialer	NO (Note 2)	**YES**	**YES**
DOS Functions	NO (Note 1)	NO	**YES**
Game	**YES**	NO	NO
ASCII Chart	NO	**YES**	NO
COST - PROTECTED	**$49.95**	$54.95	$149.95
COST - UNPROTECTED	**$84.95**	$84.95	NO/Not Avail.

Note 1: **"PolyWindows DOS"** add-on available soon at extra cost to add cut & paste and many additional functions.

Note 2: **"PolyWindows Phone"** add-on available soon at extra cost to add auto-dial, phone log, cost computation, etc.

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encryption is in securing medical records. Patient records are usually computerized and must be accessed by a variety of agencies, from hospitals to insurance agencies; there is, however, a need to keep such material as medication and disease records confidential. For example, the paranoid millionaire programmer mentioned above would not want anyone to know that his anxiety over computer security forced him to obtain yet another prescription for a sedative or that he recently contracted a socially delicate disease.

The following sections introduce modern encryption, with special emphasis on how it can be used to enhance microcomputer data security; after this introduction, a simple utility program for encryption is provided.

CLASSICAL ENCRYPTION

Cryptology is the broad term that encompasses the designing of encryption schemes, which is called *cryptography*, and the deciphering or breaking of codes, which is called *cryptanalysis*. This article is more concerned with cryptography than with cryptanalysis, although some ideas of how codes are broken are interspersed in the discussion. Only a few historical references are mentioned during the discussion of classical methods of encryption. The interested reader can consult D. Kahn's *The Code Breakers* (Weidenfeld and Nicolson, 1967), which is a nontechnical book that treats the fascinating history of encryption in some detail.

One of the earliest methods of encrypting, or *enciphering*, messages was devised by Julius Caesar. This method replaces each letter in the original message, called the *plaintext*, with the letter that is three positions farther along in the alphabet. Thus, *a* becomes *d*, *b* becomes *e*, *z* becomes *c*, etc. The encrypted text is known as the *ciphertext*. An example of this simplest of *substitution ciphers* follows, where the first line is the plaintext and the second line is the ciphertext:

```
ATTACK  CARTHAGE
dwwdfn  fduwkdjh
```

Such simple substitution schemes may have fooled Caesar's enemies, but these methods must be generalized to be of any use in modern systems.

Another ancient form of encryption used by the ancient Greeks, especially the Spartans, was the *scytale*, shown in figure 1. A long strip of papyrus was wrapped around a cylinder and the message, or plaintext, was written in the normal left-to-right manner in lines parallel to the long axis of the cylinder. It was essential for the deciphering of the code that the receiver wrap the papyrus strip around a cylinder of the same radius. The cylinder radius was the *key* to the encryption. The scytale was perhaps the first machine used to aid encryption, a job now performed by our most powerful computers. A scytale performs a *transposition cipher*, so-called because the positions, not the identities, of the characters in the plaintext have been changed. Generalized forms of ciphers using transposition and substitution with unique keys combine to form the heart of modern encryption methods.

Three types of cryptanalysis attacks by intruders must be anticipated by anyone devising an enciphering scheme: first, the *ciphertext only* attack, which is present when the intruder or enemy has access only to ciphertext; second, the *known plaintext* attack, which is present when the intruder knows the plaintext and corresponding ciphertext; third, the *chosen plaintext* attack, which is present when the enemy can select the plaintext he wishes encrypted. The last type of attack is the most dangerous.

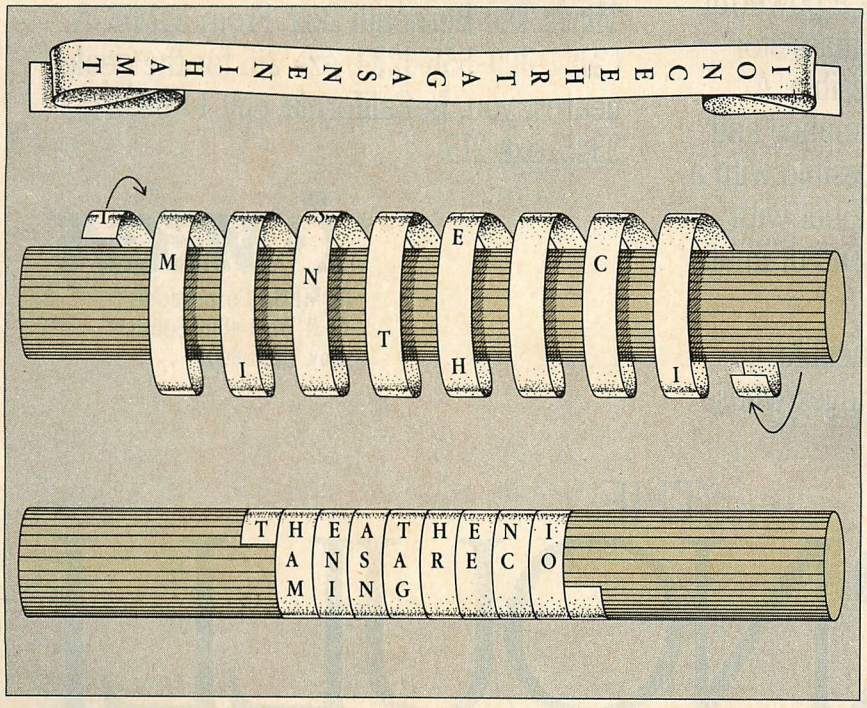
Two general modes of intrusion exist: passive and active. A passive intruder simply reads sensitive data, whereas an active one modifies or substitutes data for the original. Generally it is assumed that the encryption algorithm is publicly known and the key is kept secret and frequently changed. Security thus resides in the secrecy of the key and the proper design of the encryption algorithm rather than in the ability to keep the algorithm secret.

Figure 2 illustrates the general encryption model, with P representing plaintext, C representing ciphertext, and the function $E_k(P)$ being the operation of the encryption algorithm on P with a key of k. Decryption is usually the inverse of encryption with the same key; thus, $P=E_k^{-1}(C)$.

Early in the evolution of encryption, codes or code books were introduced that allowed for the translation of plaintext into ciphertext word by word or a phrase at a time rather than character by character or in large blocks of characters. For example, a code book might translate every reference to IBM into "789" or perhaps "Goliath" (not a very clever code, but you get the idea). Generally, a foreign language dictionary can be thought of as a code book.

The trouble with code books, and the main reason that they have fallen out of use, is that in this case the key is the entire code book, which is usually larger than the messages encoded. Changing code books frequently is difficult. (Imagine, for instance, the difficulty of switching languages every day in a military communications system.)

FIGURE 1: *The Scytale*



The scytale used by the Spartans performed a transposition cipher. The message was written on a long strip of papyrus that was wrapped around a cylinder. The code was deciphered by wrapping the papyrus strip around a cylinder of the same radius.

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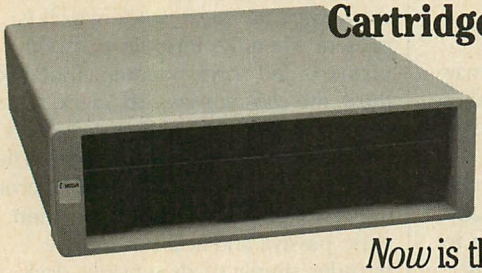

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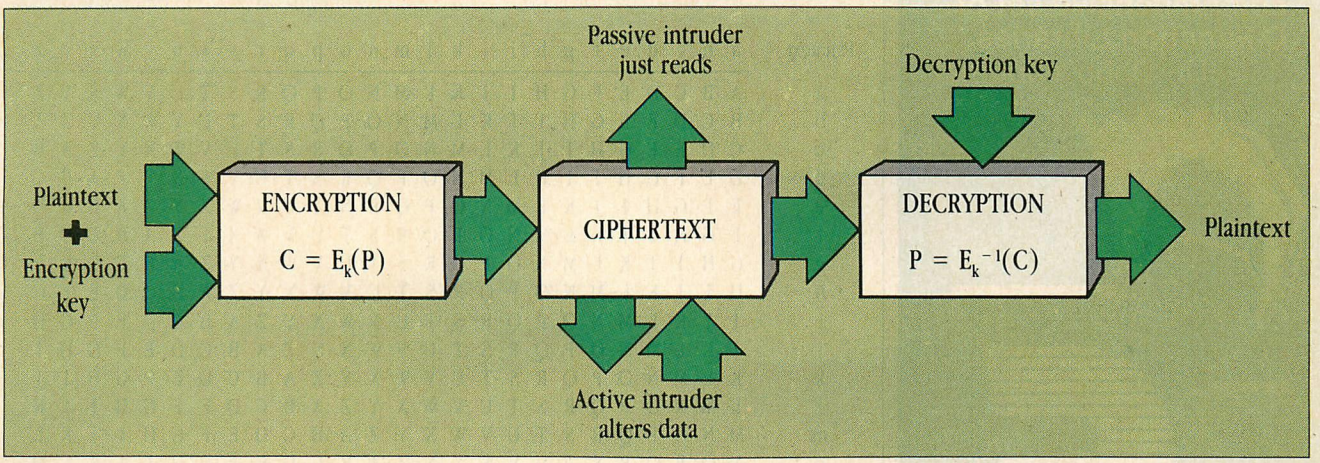
FIGURE 2: *General Encryption Model*



$E_k(P)$, the encryption algorithm on plaintext P with key k, yields the ciphertext C. Decryption is usually the inverse of encryption with the same key, so that $P = E_k^{-1}(C)$. The encryption algorithm and key must withstand attacks by intruders.

Another early development was the use of stenography—for example, invisible inks, micro dots, messages encoded in pictures, etc. Like code books, stenography has fallen out of use.

Cryptographers, whether employed by generals, diplomats, kings, or popes, soon developed more sophisticated forms of substitution and transposition ciphers. It is obvious that the Caesar cipher, which uses a shift of three characters in the alphabet, can be generalized by allowing any size shift. On the IBM PC, the amount of shift could be any number mod 128 (assuming that the 128 characters of the 7-bit ASCII code are being used). The amount of shift is then the key to this cipher. Because of the nature of language, however, this form of encryption is easy to break.

Figure 3 shows a table of the frequency of occurrences of letters in the English language. It comes as no surprise that the letter *e* occurs more often than any other letter. (It occurred 11 times in the previous sentence!) Having this statistical information makes it easy to find the encryption key: the most frequently occurring letter in the ciphertext is located and then the number of characters between that letter and the letter *e* is determined. The number of characters between these two letters is the shift amount, which is the key to this form of encryption.

Besides knowing the frequency distribution of single characters, it is important to know the frequency distribution of pairs of letters (digrams) and triplets of letters (trigrams), along with the frequency of letters that begin and end words, the frequency of types of punctuation, etc. (The most common digram is *th* and the most common trigram and word is *the*.)

A popular and more potent form of generalizing the substitution cipher is the Vigenere cipher, which employs the table shown in figure 4. A code word is used to determine which of the 26 possible shifted alphabets shown in the table is used for the substitution of a given character. This illustrates the procedure using *software* as the key.

The key is repeated as many times as necessary to give a string as long as the message. Each letter in the key determines the substitution alphabet to be used for the corresponding letter in the plaintext. For example, *s* determines that the alphabet given in the row that begins with *s* should be used to find the substitution for *t*, which is *l*; *o* determines that the alphabet in the row beginning with *o* should be used to find the substitution for *h*, which is *v*; and so on to the end.

The beauty of this form is that the same plaintext letter is not always mapped into the same ciphertext letter.

FIGURE 3: *Percent Occurrences of English Letters*

LETTERS		DIGRAMS		TRIGRAMS		WORDS	
E	13.05	TH	3.16	THE	4.72	THE	6.42
T	9.02	IN	1.54	ING	1.42	OF	4.02
O	8.21	ER	1.33	AND	1.13	AND	3.15
A	7.81	RE	1.30	ION	1.00	TO	2.36
N	7.28	AN	1.08	ENT	0.98	A	2.09
I	6.77	HE	1.08	FOR	0.76	IN	1.77
R	6.64	AR	1.02	TIO	0.75	THAT	1.25
S	6.46	EN	1.02	ERE	0.69	IS	1.03
H	5.85	TI	1.02	HER	0.68	I	0.94
D	4.11	TE	0.98	ATE	0.66	IT	0.93
L	3.60	AT	0.88	VER	0.63	FOR	0.77
C	2.93	ON	0.84	TER	0.62	AS	0.76
F	2.88	HA	0.84	THA	0.62	WITH	0.76
U	2.77	OU	0.72	ATI	0.59	WAS	0.72
M	2.62	IT	0.71	HAT	0.55	HIS	0.71
P	2.15	ES	0.69	ERS	0.54	HE	0.71
Y	1.51	ST	0.68	HIS	0.52	BE	0.63
W	1.49	OR	0.68	RES	0.50	NOT	0.61
G	1.39	NT	0.67	ILL	0.47	BY	0.57
B	1.28	HI	0.66	ARE	0.46	BUT	0.56
V	1.00	EA	0.64	CON	0.45	HAVE	0.55
K	0.42	VE	0.64	NCE	0.43	YOU	0.55
X	0.30	CO	0.59	ALL	0.44	WHICH	0.53
J	0.23	DE	0.55	EVE	0.44	ARE	0.50
Q	0.14	RA	0.55	ITH	0.44	ON	0.47
Z	0.09	RO	0.55	TED	0.44	OR	0.45

Statistics on the frequency of occurrences of letters, digrams, trigrams, and words allow an easy cryptanalysis of messages encrypted using the generalized Caesar cipher. Information like this is essential in breaking more sophisticated schemas.

FIGURE 4: *Vigenere Square*

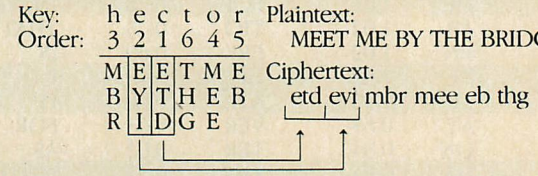
Plaintext	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
a	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
c	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
d	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
e	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
f	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
g	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
h	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
i	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
j	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
k	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
l	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
m	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
n	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
o	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
p	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
q	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
r	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
s	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
t	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
u	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
v	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
w	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
x	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
y	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
z	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y

Sample encryption

Key:	soft wa r esoftw aresoft
Plaintext:	this is a secret message
Ciphertext:	lvnl es r wwqwxp mvwkolx

In the Vigenere cipher, a code word is used to determine which of the 26 possible shifted alphabets shown in the Vigenere Square above is used for the substitution of a given character in the plaintext. The code word (software, in this example) is repeated as many times as is necessary.

FIGURE 5: *Columnar Transposition*



The ciphertext is created by reading columns of text, starting with the text under the letter in the key that is closest to the beginning of the alphabet, followed by the next closest letter and so on. In this example HECTOR is the key.

For example, the first *e* becomes *w*, but the second *e* becomes *x*. Although this makes the cryptanalysis more difficult, relatively simple ways of breaking the Vigenere cipher still exist.

Only one method of encryption—the *one-time-pad*—is fully secure or unbreakable, meaning that the cryptanalyst obtains no information whatsoever from his intercepted ciphertext. No other known form of encryption can be mathematically proven to be unbreakable. In all other cases the best that can be done is to estimate the difficulty of breaking the encryption, assuming that the intruder would be able to use a *chosen plaintext* or *known plaintext* attack. The estimate is usually made in terms of the number of CPU hours of mainframe time required to find the key. Of course, such estimates are not totally reliable, because someone could

invent a more efficient algorithm for breaking the cipher than was used in the original estimate.

In other words, without a rigorous mathematical proof a cipher may not be as strong as even the most pessimistic estimates claim. Finding rigorous mathematical estimates of cryptographic strength involves using the discipline known as computational complexity theory and is an active research area.

Understanding the one-time-pad encryption method requires a knowledge of the exclusive-or operation, usually symbolized as XOR. The following table defines XOR as it relates to the binary values 0 and 1.

A	*B*	*A* XOR *B*
1	1	0
1	0	1
0	1	1
0	0	0

Assume that the message to be encrypted is *n* bits long and that a truly random string of *n* bits is generated as the key. (Finding a truly random bit string is not easy. Computer language implementations of random-number generators are only pseudo-random, because they have regularities with a relatively short repetition period.) Performing an XOR between the message and the key, which can never be used again, gives the unbreakable one-time-pad.

This form of substitution cipher is extremely clumsy, because the key can be used only once and is always at least as long as the message. The secure distribution of keys is a formidable problem. Despite this difficulty, the Soviet Union is reported to use this method for its most sensitive communications.

Each of the various forms of substitution ciphers can be used in *stream encryption*, in which one character at a time is encrypted. Transposition ciphers, such as the Greek scytale, must be performed on blocks of plaintext and hence can be used only in some form of *block encryption*.

A common transposition cipher that allows for a more interesting key than the radius of the cylinder of the scytale is the columnar transposition. The encryption is keyed by a word or phrase that has no repeated letters. In the example given in figure 5, *hector* is used as the key. The key allows the columns to be numbered, column 1 being under the key letter closest to the beginning of the alphabet (in this case, *c*), column 2 being under the key letter next closest to the start of the alphabet (in this case, *e*), etc. The ciphertext is

created using the columns of text starting with the column whose key letter is closest to the beginning of the alphabet followed by the column of text under the letter next closest to the beginning of the alphabet, and so on.

Long keys generated by sequences of pseudo-random numbers that determine the order of transposition or permutation of the characters in the block permit a generalization of the transposition method. A concrete example of this method is given in the simple utility program for encryption presented in listing 1. Although transposition maintains the frequency of occurrences of each character, all digrams, trigrams, etc., are necessarily broken up.

WARTIME DEVELOPMENTS

As the need for encryption increased in modern times, various machines were devised to speed up the process of enciphering messages. One example of such a machine is the Hagelin C-48, widely used by Americans during World War II and the Korean War; it had the military designation M-209.

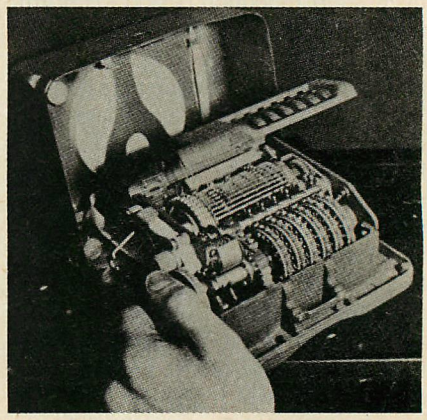
The Hagelin C-48's method closely resembles those of the Vigenere cipher discussed above. The two major components are the key wheels, which generate a long pseudo-random sequence of 6-bit groups, and the cage, which transforms the 6-bit groups into characters. The key is chosen by making initial adjustments to the key wheels. For a complete mechanical description of the machine, see Kahn's *The Code Breakers*. According to W. Diffie and M. Hellman (*IEEE*, March 1979, pages 397-427), using modern techniques, attacks of the known-plaintext type on ciphertext created by this machine can succeed with only 50 to 100 characters of text, and ciphertext-only attacks can succeed with only 1,000 to 2,000 characters.

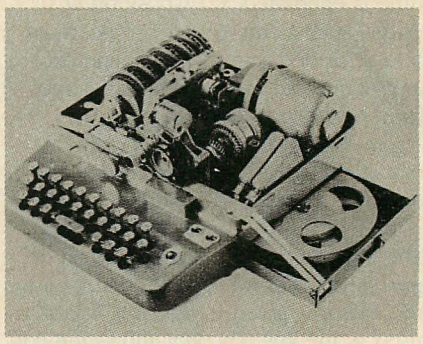
The most important cryptographic device in World War II was the rotor machine. These machines remained dominant until the 1950s. In this class are the SIGABA, the highest-level American system; the British TYPEX; and the German ENIGMA. Rotor machines are generalized transposition ciphers. *The Code Breakers* (Kahn 1967) tells the fascinating story of how these machines operated and how the German ENIGMA codes were broken.

The first electronic digital computer, the Colossus, was built by the British for the deciphering of the German ENIGMA code. See *A History of Computing in the Twentieth Century*, (Metropolis et al. 1980). The Colossus became operational in December 1943, six months earlier than the Mark I at Harvard University, which most people consider to be the oldest computer. The breaking of the German code, a combined effort of the Polish and British forces, and the breaking of the Japanese code by the Americans played a central role in World War II military intelligence. The best estimates are that the Pacific War alone was shortened by one year because of the breaking of the Japanese code.

The two main applications of encryption for microcomputers are in communications and file security. As more micros are networked together it becomes increasingly difficult to maintain control over sensitive data. Even relatively small local area networks often go between buildings or in areas that are easily subjected to wiretapping.

Although wiretapping may not be a threat, users nonetheless may wish to have more assurance that data going out on the common bus are secure from being read or modified by other users on the same network. Of course, if the network hardware and software were perfect, each user would be effectively separated from his neighbor, but such perfection is far from the real world. In the case of national networks





Photographs courtesy of David Kahn, *The Code Breakers*

Encryption machines such as these two shown here played a significant role in World War II. The Hagelin C-48 (top) used a substitution cipher similar to the Vigenere, and the O.M.I. rotor cipher machine (bottom) used a transposition type cipher.

the problem is more severe because there are many sites for wiretaps. It is possible to set up a microwave receiver to obtain all data flowing through an important part of the network.

In networks, maximum security is obtained by encrypting in the same place where the data is generated or used, whether it be a micro or mainframe. The encrypted file is decrypted at the receiver's end.

Several difficulties with this scheme do exist. One problem is how the key for encryption is to be transmitted to the desired receiver. In simple situations it can be sent in the mail or encrypted inside another message, but the problem is severe in some situations.

For example, a large financial institution with many branches must have a high level of security for its financial transactions. Say the institution has n sites, which may be any type of computer, that require secure communications. To maintain security the institution wishes to change its keys at least once a day. In general, the more frequently keys are changed the more secure the system. Each of the n sites wishes to communicate securely with every other site, so there are $n(n\text{-}1)/2$ distinct pairs. Even a modest $n=100$ means that 4,950 keys must be changed each day.

In a more specific example, the world's largest private bank, Citicorp, has 2,789 offices throughout the world. Assuming that each office has only one site that requires secure communication with all other sites, 3,887,866 keys must be securely distributed each time new keys are desired. In very sensitive situations it is not adequate to use an old key to encrypt the new key, because that could be giving the new key away.

These remarks alone make it clear that the secure distribution of keys is a major problem. Part 2 of this article will look at the public-key-encryption scheme of Diffie and Hellman, which solves this problem with great elegance.

Another problem that is not solved by end-to-end encryption as described above is how to thwart traffic analysis—that is, how to prevent someone from keeping track of the overall flow of message traffic. Because in end-to-end encryption the message headers containing the addresses of the sender and the receiver must be plaintext in order for the network to properly route messages, an intruder can always find out who is doing a lot of communicating, even if the messages themselves cannot actually be deciphered.

Obviously, traffic analysis can be an important piece of intelligence in a mil-

itary situation; it can also be of use in some commercial situations. (For example, a big deal must be afoot judging from the amount of traffic between a certain company's Dallas and San Francisco branches. . . .) Traffic analysis can be thwarted by inserting dummy messages into the traffic flow, but this also has the adverse effect of increasing the overhead on the network.

One method that reduces the chances of traffic analysis is link encryption. In link encryption, the packets are entirely encrypted (including the headers) between the nodes and entirely plaintext within each node. In addition to reducing the traffic analysis problem, link encryption sometimes makes the key distribution problem easier to solve. This method suffers, however, from a reliance on the correctness of the routing system within each node. Any mistakes in routing can compromise the security of the system.

Aside from communications security, encryption can be used to enhance file security. The millionaire programmer mentioned at the beginning of this article knew that security is not guaranteed even in operating systems that have password protection for individual files. Many languages, especially assembly language, can access any region in memory or any system resource in most microcomputers.

The problem lies with the limitations of most microcomputer hardware. In contrast to mini and mainframe computers, which have hardware-enforced privilege domains made up of regions of memory and selected computer resources that cannot be accessed by application programs, microcomputers generally use central processors in the class of the Intel 8088, which cannot distinguish between operating system commands and those of applications programs. Therefore, anyone with a good working knowledge of systems programming usually can defeat most any non-hardware-enforced security system. For this reason the millionaire programmer's files on the microcomputer hard disk that he shared with others were not secure.

In the sample program presented in listing 1, two rather long keys are generated using a pseudo-random-number generator. The keys, along with the encryption and decryption program, are stored on a separate floppy, called the Decryption-Encryption Floppy (DEF). When decryption or encryption of a file is needed, the DEF is inserted and the program is run. Thus, only one DEF needs to be secured. It can be locked when not in use or given to someone else to use for legitimate file access. Because separate keys can be placed on different DEFs, secure separation of files can be obtained.

The use of DEFs may not be the most convenient method, but it is certainly inexpensive and it offers a relatively high degree of security for both files and communications. As with any other files, the programs on the DEF, the key file, and the encrypted files must be carefully backed up. Losing your car keys just requires a locksmith to fit a new key to your ignition; losing an encryption key is a loss of all the files encrypted under that key. Increased security has its price.

AN ENCRYPTION EXAMPLE

Although both substitution and transposition ciphers can be broken with relative ease, when they are applied successively to the same plaintext a considerably more secure *product cipher* is generated. Concatenation of product ciphers again increases cryptographic strength. Another way of increasing

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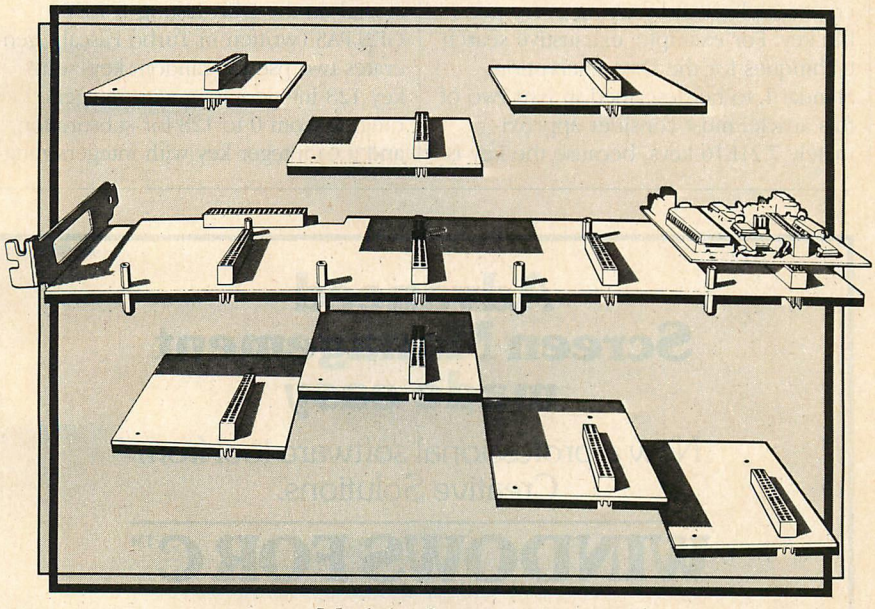

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CIRCLE NO. 108 ON READER SERVICE CARD

strength is to use long keys. In this case, the key space (the space required by all possible keys) is exceedingly large, which rules out any exhaustive key-search techniques.

Key-search techniques are brute-force methods that, assuming the encryption algorithm is known, try to decrypt a ciphertext by trying every possible key. For example, exhaustive search techniques for the Data Encryption Standard, to be described in part two of this article, must consider approximately 7.21E16 keys, because the key is 56 bits long and there are thus 2^{56} possible keys. As will be explained in the second part of this article, some experts consider this to be too small a number.

In some applications long keys are impractical, but they present no problems when used with the method in listing 1, because they are automatically stored on the DEF. Listing 1, KEYGEN.PAS (written in Turbo Pascal), generates two pseudo-random keys: one key 128 integers long with integers ranging from 0 to 128 for substitution, and a 64-integer key with integers ranging from 0 to 64 for transposition. If the random-number generator were truly random, the key space would contain 2^{1280}, or 2.08E385, keys. In this case it is safe to say that exhaustive key searches are out of the question for even the most exotic computers of the future.

However, although I do not know what Turbo Pascal's random-number generation algorithm is, it is certainly not truly random; thus, the real key space is no doubt much smaller than the monster number just quoted. In any case, it is possible that more intelligent approaches than exhaustive searching could break the simple encryption algorithm used in listing 1.

The substitution key is generated by simply putting 128 pseudo-random numbers, ranging from 0 to 128, in an array called **subKey**. The transposition key is made by generating an integer array with consecutive integers 1 through 64 and then swapping them within the array using the pseudo-random-number generator to give **transKey**. After checking that the elements of transKey add up to the sum of the integers 1 through 64, the program then writes these keys to the file called **keyfile**. **Keyfile** is read by the main program for encryption and decryption. The built-in function **randomize** is called twice to insure that the seed for each use of the pseudo-random-number generator is different.

The encryption program requires that careful track be kept of which files are encrypted under which keys. It is best to change keys infrequently and to write-protect the DEF so that new keys are not unwittingly generated. If an attempt to decrypt a file with the wrong key is made, the mistake will be immediately evident; encrypting the file by the same key will undo the mistake.

Listing 2, ENCIPHER.PAS (also written in Turbo Pascal), both encrypts and decrypts files. After the procedure **initialize** reads in the two keys in **keyfile**, the user is prompted to specify encryption or decryption. If encryption is desired, the procedure **readfile** reads in the file to be encrypted and finds the file size. All reads and writes are done through the Turbo procedures **BlockRead** and **BlockWrite**, which are faster than the standard read and write procedures. These procedures operate on blocks of 128 bytes, which is also the size chosen for the program's block form of encryption.

The procedure **encrypt** performs a substitution using **subKey**, after which procedure **transpose** performs a transposition that transposes 64 characters

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with the next 64 characters using **transKey**. The resulting product cipher is then subjected to another substitution by procedure **logicalXor**, which performs a logical XOR of the file with **subKey**. Both substitution procedures use the entire 256-character extended ASCII code. Finally, the ciphertext is written out by the procedure **writeFile**. The decryption process basically just reverses the steps described above.

Along the way in this process, various safety checks are performed, because a faulty encryption or decryption program can function like an extremely effective deletion program. For example, just before the encrypted file is written over the plaintext, the user is asked if this substitution is really what is wanted. If the answer is no, the original file is left intact and no overwrite occurs. If the answer is yes, the original file is overwritten with the encrypted file and given the extension .ENC. When the file is decrypted, it is given the extension .CLR. It is important to write over the original file and not just to delete it. In PC-DOS and other operating systems, deleted files are still intact, ready to be gathered up by any number of utility programs, such as the Norton Utility Unerase.

The procedure **writeFile** also has a procedure **fileExist** that checks to see that the change in file name generated by the encryption or decryption does not conflict with an already existing file. If it does, the original file name is retained and the user receives a warning.

Any type of file, whether machine language or text, can be encrypted. It is also possible to encrypt the same file more than once, although the program will send warning messages about filename conflicts, as it should. If a file is triply encrypted, it will require a triple decryption. The program is quite fast, in part because of the **BlockWrite** and **BlockRead** procedures; thus, encrypting even large files is a matter of seconds.

When first experimenting with this program, be sure that all files to be encrypted or decrypted are properly backed up. Also, don't panic if the TYPE command produces a file that seems extremely short, because the first Ctrl-Z generated by the encryption will be recognized by TYPE as an end-of-file mark.

Because of uncertainties mentioned about the pseudo-random-number generator and because it is difficult to accurately assess the cryptographic strength of a given algorithm, it is hard to say just how strong the above algorithm is. It seems adequate for modest security needs, but never underestimate the talent of good cryptanalysts. I make no claims for the strength of the algorithm.

Other encryption methods—for example, the Data Encryption Standard approved by the National Bureau of Standards for commercial use and the Public Key System implementation of Rivset, Shamir, and Adleman—will be discussed in the second part of this article. These encryption schemes are commercially available for the PC.

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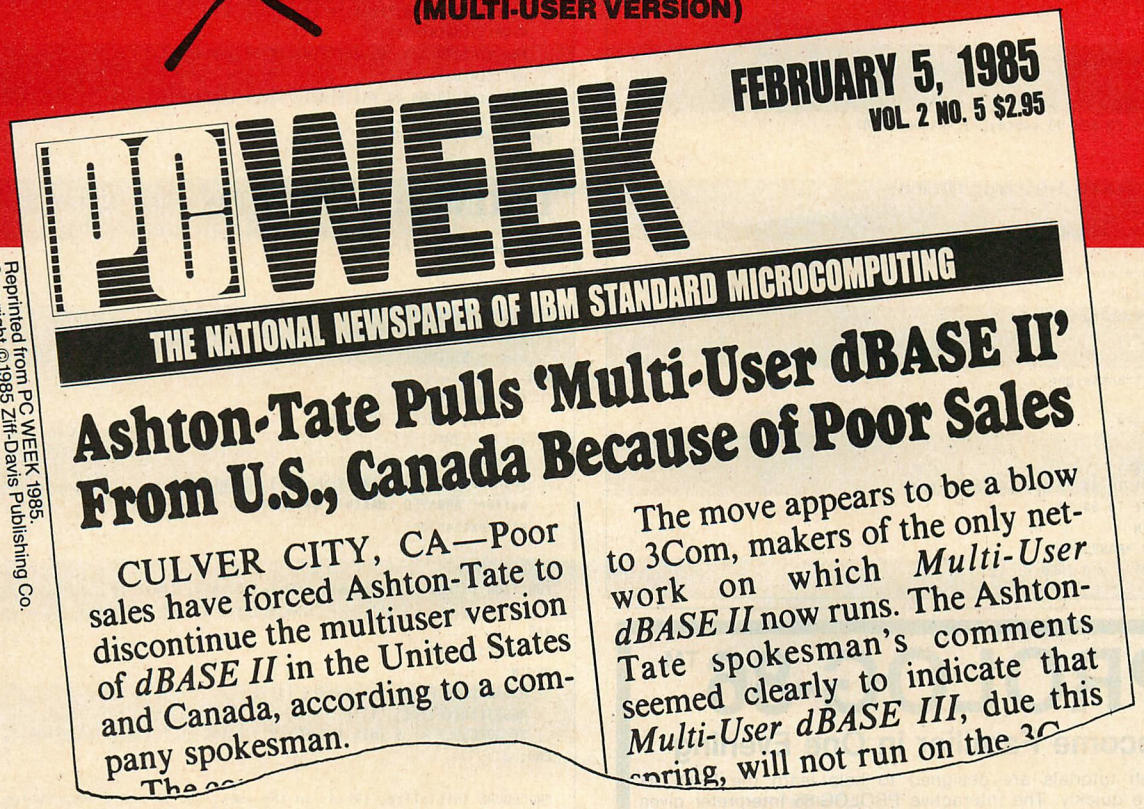
Victor Mansfield is chairman of the department of physics, associate professor of physics and astronomy, and adjunct professor of computer science at Colgate University. For the past few years he has worked as a consultant in computer security and formal verification of software correctness.

discontinued

dBASE II

(MULTI-USER VERSION)



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CIRCLE NO. 132 ON READER SERVICE CARD

LISTING 1: KEYGEN.PAS

```
PROGRAM keygen;

{$R+}
TYPE
   subrange1 = 1..128;
   subrange2 = 1..64;
VAR
   i: subrange1;
   j: subrange2;
   sum, keysum: INTEGER;
   subKey: ARRAY[1..128] OF INTEGER;
   transKey: ARRAY[1..64] OF INTEGER;
   datafile: TEXT;


PROCEDURE subKeygen;
BEGIN
   RANDOMIZE;
   FOR i:=1 TO 128 DO subKey[i]:=RANDOM(128);
END;

PROCEDURE swap(VAR left,right: INTEGER);
VAR
   tempStore: INTEGER;
BEGIN
   tempStore:=left;
   left:=right;
   right:=tempStore;
END;

PROCEDURE transKeygen;
VAR
   r: INTEGER;
BEGIN
   RANDOMIZE;
   FOR j:=1 TO 64 DO transKey[j]:=j;
   FOR j:=1 TO 64 DO
      BEGIN
         r:=RANDOM(65);
         IF r = 0 THEN r:=1;
         swap(transKey[j],transKey[r]);
      END;
END;

BEGIN
   subKeygen;
   transKeygen;
   sum:=0; keysum:=0;
   FOR j:=1 TO 64 DO
      BEGIN
         sum:=sum+j;

         keysum:=transKey[j] + keysum;
      END;
   WRITELN('Sum =',sum,'  Keysum =',keysum);
   ASSIGN(datafile,'keyfile');
   REWRITE(datafile);
   FOR i:=1 TO 128  DO WRITE(datafile,subKey[i],' ');
   WRITELN(datafile);
   FOR j:=1 TO 64 DO WRITE(datafile,transKey[j],' ');
   CLOSE(datafile);
END.
```

LISTING 2: ENCIPHER.PAS

```
PROGRAM ENCIPHER(fileName);


TYPE
   extension = STRING[4];
   name = STRING[14];
VAR
   fileName: FILE;
   i, stop, blocks: INTEGER;
   answer: CHAR;
   fileIn: name;
   transKey, subKey: ARRAY[0..127] OF INTEGER;
   buffer: ARRAY[0..MAXINT] OF CHAR;
   ext: extension;


FUNCTION fileExist(fileName: name): BOOLEAN; {Test to
                                see if file already exists.}
VAR
   testFile: FILE;
BEGIN
   ASSIGN(testFile, fileName); {$I-}
   RESET(testFile); {$I+}
   IF IORESULT <> 0 THEN fileExist:= FALSE ELSE fileExist:=TRUE;
END;

PROCEDURE initialize; {Reads in the substitution and transposition
                       keys from keyFile.}
VAR
   dataFile: TEXT;
BEGIN
   ASSIGN(dataFile,'keyFile');
   RESET(dataFile);
   FOR i:= 0 TO 127 DO READ(dataFile,subKey[i]);
   READLN(dataFile);
   FOR i:= 0 TO 63 DO READ(dataFile,transKey[i]);
   CLOSE(dataFile);
END; {of initialize}

PROCEDURE transpose; {Transposes 64 characters with the next 64
                      using the transpose key.}
VAR
   tempstore: CHAR;
   switchIndex, increment: INTEGER;
BEGIN
   increment:= 63;  i:= 0;
   WHILE i < stop DO
      BEGIN
         tempstore:= buffer[i];
         switchIndex:= increment + transKey[i MOD 64];
         buffer[i]:= buffer[switchIndex];
         buffer[switchIndex]:= tempstore;
         i:= i+1;
         IF i MOD 64 = 0 THEN
            BEGIN
               i:= i + 64;
               increment:= increment + 128;
            END;
      END;
END; {of transpose}
```

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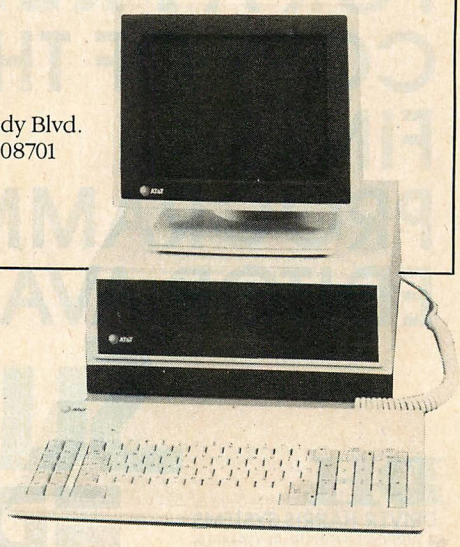

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```
PROCEDURE logicalXor; {Performs a logical xor of the file with the
                       substitution key.}
BEGIN
   FOR i:= 0 TO stop - 1 DO
   buffer[i]:= CHR(ORD(buffer[i]) XOR subKey[i MOD 128]);
END; {of logicalXor}

PROCEDURE readFile; {Reads in the file to be encrypted or decrypted
                     and finds the file size.}
BEGIN
   READLN(fileIn);
   WRITELN;
   ASSIGN(fileName,fileIn);
   RESET(fileName);
   blocks:= FILESIZE(fileName);
   stop:= 128*blocks - 1;
   BLOCKREAD(fileName,buffer,blocks);
   CLOSE(fileName);
END; {of readFile}

PROCEDURE writeFile(VAR ext: extension);  {Writes the encrypted or
                                 decrypted file and renames with ext.}
VAR
   period: INTEGER;
BEGIN
   CASE answer OF
   'E','e': WRITELN(fileIn,' is to be ENCRYPTED.  Enter Y or N.');
   'D','d': WRITELN(fileIn,' is to be DECRYPTED.  Enter Y or N.');
   END;
   READLN(answer);
   IF answer IN ['y','Y'] THEN
     BEGIN
        REWRITE(fileName);
        BLOCKWRITE(fileName,buffer,blocks);
        CLOSE(fileName);
        period:= POS('.',fileIn);
        IF period > 0 THEN DELETE(fileIn,period,4);
        fileIn:= fileIn + ext;
        IF fileExist(fileIn) THEN
        WRITELN('NOTE! DUPLICATE NAMES. ORIGINAL FILE NAME KEPT.')
        ELSE RENAME(fileName,fileIn);
     END
   ELSE WRITELN('FINAL FILE NOT WRITTEN.  ORIGINAL FILE INTACT.');
END; {of writeFile}

PROCEDURE encrypt; {Encryption as substitution, transposition,
                    and logical xor.}
BEGIN
   WRITELN('Enter the name of the file you wish to ENCRYPT:');
   readFile;
   FOR i:= 0 TO stop-1 DO
   buffer[i]:= CHR(ORD(buffer[i]) + subKey[i MOD 128]);
   transpose;
   logicalXor;
   ext:= '.enc';
   writeFile(ext);
END; {of encrypt}
PROCEDURE decrypt; {Decryption as the inverse of encryption.}

BEGIN
   WRITELN('Enter the name of the file you wish to DECRYPT');
   readFile;
   logicalXor;
   transpose;
   FOR i:= 0 TO stop-1 DO
   buffer[i]:= CHR(ORD(buffer[i]) - subKey[i MOD 128]);
   ext:= '.clr';
   writeFile(ext);
END; {of decrypt}

{ ***** END OF PROCEDURES ***** }

BEGIN
   initialize;
   WRITELN('Encrypt, Decrypt, or Terminate (E/D/T)?');
   WRITELN;
   READLN(answer);
   CASE answer OF
   'E','e': encrypt;
   'D','d': decrypt;
   'T','t': WRITELN('TERMINATING. NO ACTION TAKEN.');
   ELSE WRITELN('ILLEGAL RESPONSE. TERMINATING. NO ACTION TAKEN.');
   END;
END.
```

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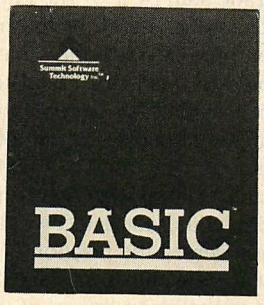

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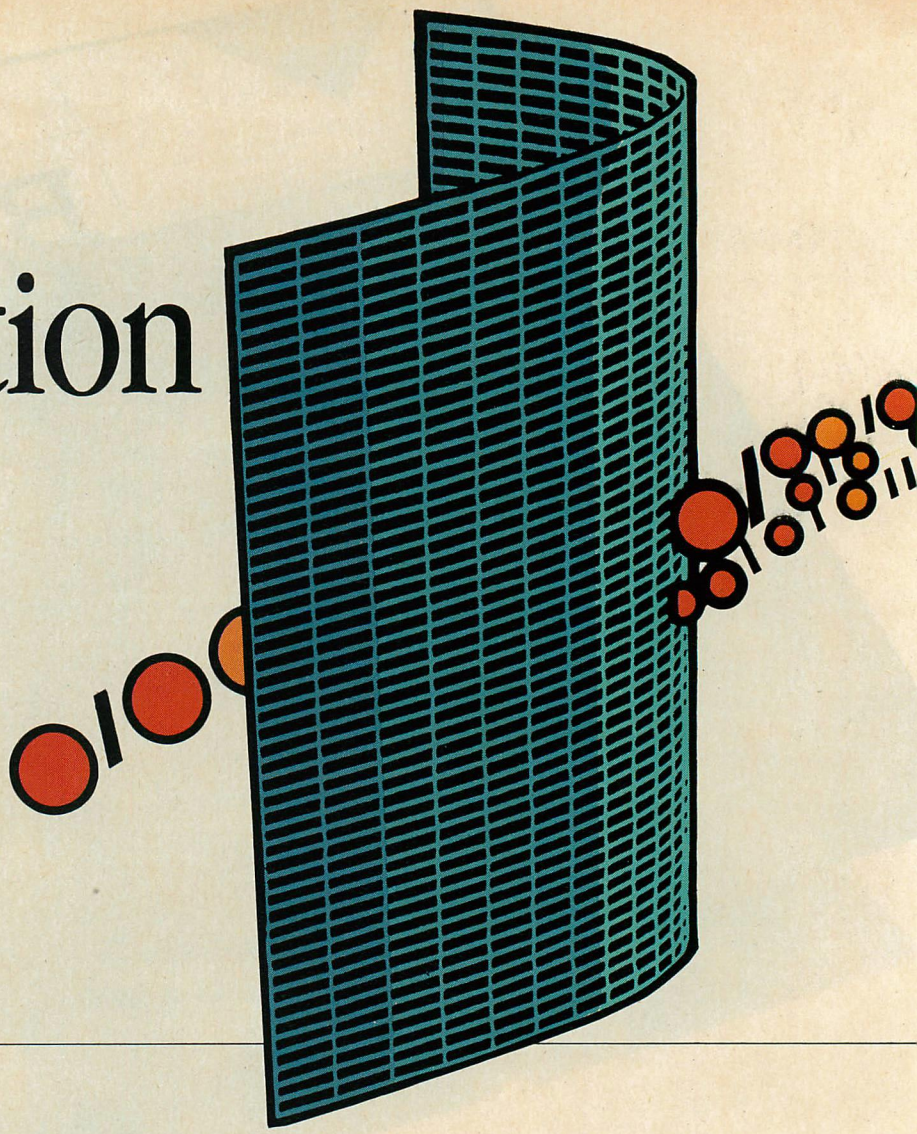


W. DAVID SCHWADERER

Over the years many methods have been developed to detect potential data transmission errors. The most pervasive approach is a *message cyclic redundancy check* (CRC), in which a value is generated from individual data characters within a message and included as the final part of the message. When the message arrives at its destination, the receiving machine uses an identical process to calculate a CRC and compares this independent CRC with the one it received. If the two CRCs do not match, an error has occurred and the communications session proceeds under the protocol's error recovery provisions.

If the two CRCs do match, the chances are good that the message arrived without mishap. In truth, using a CRC does not absolutely guarantee that the data arrived wholly intact, but the cost of trying to achieve 100-percent error detection is prohibitive in most applications. Some CRC methods, however, are more effective than others.

As an example, Ward Christensen's XMODEM protocol computes a CRC-like value (technically a checksum) for each message by adding together the binary values of the message characters and dividing the sum by 256. The one-byte remainder value is used in an error-detection process much the same as a CRC would be. Statistical calculations indicate that XMODEM's approach will detect about 95 percent of all potential transmission errors for XMODEM's 128-byte character messages. An error that XMODEM would not detect would be one that reversed the position of two adjacent bytes within a message. Since the sum of the binary values of the characters would be the same, the error would go undetected.

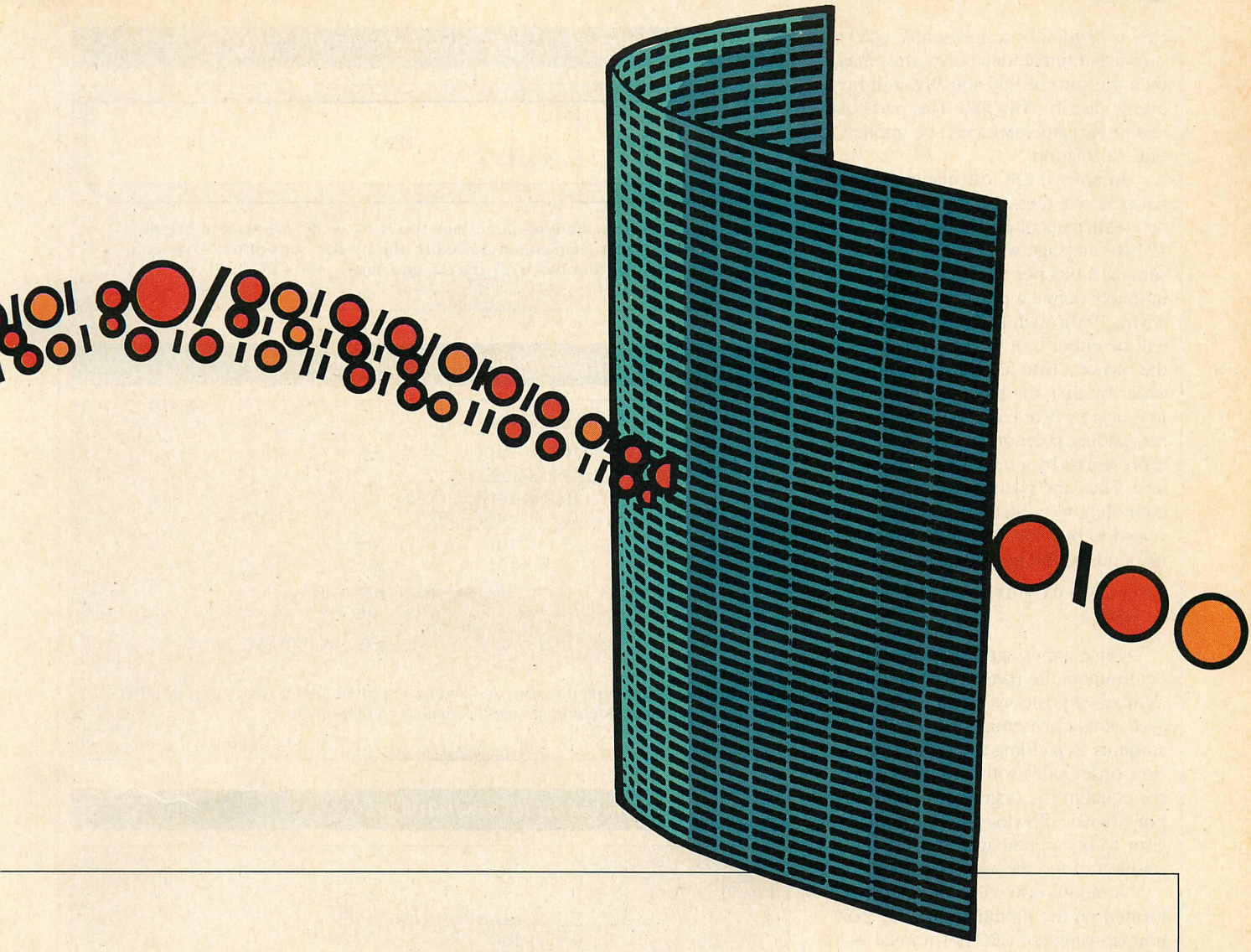
Protocols that use a CRC mechanism often transmit messages that consist of a header followed by a text section that is interpreted according to information in the header. Within a typical message (figure 1), the beginning of the header portion is indicated by an SOH character (start of header, ASCII 001). The text portion begins with an STX character (start of text, ASCII 002), which also terminates the header portion. The text portion is terminated by an ETX (end of text, ASCII 003) or ETB (end of text block, ASCII 023). The CRC follows the ETX/B character. The particular characters that are used to generate the CRC vary by specific protocol and are not addressed.

POLYNOMIAL PLEASURES

A review of some algebra 1 concepts may bring to mind the many pleasures of polynomial division. In that procedure, one algebraic polynomial can be divided by another to yield a quotient polynomial and a remainder polynomial. Consider the following polynomials:

$$F(x) = x^5 + 9x^3 + x^2 + 1$$
$$P(x) = x^2 - 1$$

Dividing $F(x)$ by $P(x)$ yields a quotient polynomial $Q(x)$ of $x^3 + 10x + 1$ and a remainder polynomial $R(x)$ of



$10x + 2$. Figure 2 demonstrates the mathematics of this process. Multiplying $P(x)$ by $Q(x)$ and adding $R(x)$ to the product gives $F(x)$ as a final result. That is, the process is reversible.

Every polynomial has a degree that is determined by the value of the highest power of x found in a term that is nonzero. In the above example, the degree of $P(x)$ is 2; the degree of $F(x)$ is 5. When one polynomial is divided by another, the remainder $R(x)$ will always have a degree less than the degree of the divisor, here $P(x)$. The degree of $R(x)$ is 1, which is less than the degree of $P(x)$. Further, the number of terms in the quotient will always be equal to, or here less than, the degree of the divisor; R(x) has two terms.

The last two terms of $F(x)$ $(0x + 1)$ are not actually divided by $P(x)$ because they are of less degree than the divisor. Their effect is seen in the remainder $R(x)$, but not the quotient $Q(x)$; that is, the divisor polynomial is not directly applied to the low-order terms of $F(x)$.

All calculations in figure 2 are done using normal decimal arithmetic. Moreover, when subtracting (or adding) one term from (to) another, there is no borrowing or carrying from an adjacent term; the coefficients of the terms are independent. Figure 3 is a shorthand illustration of the example division.

The cost of trying to achieve 100-percent error detection is prohibitive in most applications.

Modulo two arithmetic introduces a new twist to polynomial division. It is similar to base-two (binary) arithmetic, but the two are decidedly different. In base-two arithmetic $1 + 1 = 10$; in modulo two, $1 + 1 = 0$. Figure 4 has the addition and subtraction tables for this method, as well as a corresponding exclusive OR table.

Clearly, no difference exists between either of the modulo two arithmetic operations or the exclusive OR operation. Thus, the polynomial

$$F(x) = x^5 + x^3 + 1$$

can be divided by the polynomial

$$P(x) = x^2 + 1$$

using modulo two arithmetic and obtain $Q(x) = x^3$ and $R(x) = 1$, as illustrated in figure 5. In addition, if $P(x)$ is multiplied by $Q(x)$, and $R(x)$ is added to the product, the original $F(x)$ is recovered:

$$P(x) * Q(x) + R(x) = F(x)$$

Restated,

$$\begin{aligned} P(x) * Q(x) &= F(x) - R(x) \\ &= F(x) \text{ exclusive OR } R(x) \\ &= F(x) + R(x) \end{aligned}$$

Thus, it is clear that under modulo two arithmetic, if a dividend polynomial

ILLUSTRATION • CHRIS SPOLLEN

$F(x)$ is divided by a polynomial $Q(x)$ to produce a remainder polynomial $R(x)$, then the sum of $F(x)$ and $R(x)$ will be evenly divisible by $Q(X)$. This particular lesson in mathematics can be applied to CRC calculation.

In normal CRC calculation, the bit patterns of a message are considered to be coefficients of polynomials. That is, a 10-byte message will have 80 bits (assuming 8 bits per message byte) that uniquely define a polynomial with 80 terms, 79 through 0. The coefficients will be either 0 or 1. However, because the bits of a byte are transmitted low-order bit first, the bits must be reversed in a byte-by-byte basis to obtain the corresponding polynomial that is actually represented by a message's byte pattern. Thus, the character *A*, which is equivalent to a binary 01000001, is inverted to become 10000010, which corresponds to the polynomial

$$1X^7 + 0X^6 + 0X^5 + 0X^4 + 0X^3 + 0X^2 + 1X^1 + 0X^0$$

Once a message's bit pattern is determined, the pattern is shifted left a number of positions equal to the degree of its polynomial divisor. This amounts to padding the right-hand (low-order side) with a number of zeros equal to the degree of the dividing polynomial, allowing the polynomial divisor to be applied against every bit position of the message polynomial.

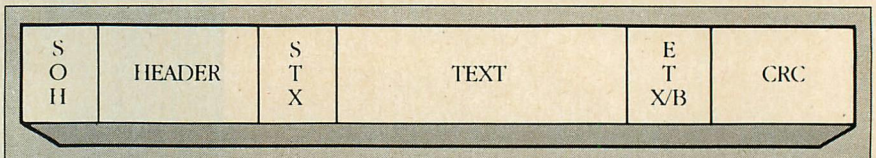
A modulo two division is now performed on the modified message polynomial using the CRC polynomial as a divisor. The resulting quotient is discarded and the remainder, the CRC, is transmitted after the rest of the message has been transmitted. The CRC is transmitted as a unit, low-order bit first, even if it consists of more than 8 bits. All the CRC bits are transmitted, including high-order zero bits.

This leaves two questions unanswered. First, what polynomial is used as a divisor polynomial; and second, how is the division of a long message polynomial done efficiently?

The mathematical theory involved in selecting an effective divisor polynomial is beyond most graduate mathematics courses. It is possible, however, to present the results of the mathematics without understanding the process that was used to arrive at them. Table 1 shows the most commonly used CRC polynomials on 8-bit data.

Because the remainder of a degree 16 divisor polynomial will be of degree 15 or less, the use of these polynomials results in a 16-bit remainder. Using these polynomials allows detection of

FIGURE 1: *Typical Message Format*



As this figure illustrates, a typical message that uses a CRC mechanism begins with a start of header character, followed by the header, start of text character, text, end of text (or text block) character, and, finally, the CRC.

FIGURE 2: *Algebraic Polynomial Division*

$$
\begin{array}{r|l}
 & x^3 + 0x^2 + 10x + 1 \quad = Q(x) \\
x^2 + 0x - 1 & x^5 + 0x^4 + 9x^3 + x^2 + 0x + 1 \\
 & x^5 + 0x^4 - x^3 \\
\hline
 & 0x^4 + 10x^3 + x^2 \\
 & 0x^4 + 0x^3 + 0x^2 \\
\hline
 & 10x^3 + x^2 + 0x \\
 & 10x^3 + 0x^2 - 10x \\
\hline
 & x^2 + 10x + 1 \\
 & x^2 + 0x - 1 \\
\hline
 & 10x + 2 = R(x)
\end{array}
$$

In algebraic polynomial division, one algebraic polynomial is divided by another to yield a quotient polynomial and a remainder polynomial.

FIGURE 3: *Shorthand Representation*

$$
\begin{array}{r|l}
 & 1\ \ 0\ \ 10\ \ 1 \\
1\ \ 0\ -1 & 1\ \ 0\ \ 9\ \ 1\ \ 0\ \ 1 \\
 & 1\ \ 0\ -1 \\
\hline
 & 0\ \ 10\ \ 1 \\
 & 0\ \ 0\ \ 0 \\
\hline
 & 10\ \ 1\ \ 0 \\
 & 10\ \ 0\ -10 \\
\hline
 & 1\ \ 10\ \ 1 \\
 & 1\ \ 0\ -1 \\
\hline
 & 10\ \ 2
\end{array}
$$

The algebraic polynomial division example that was demonstrated in figure 2 can also be represented in this shorthand form.

FIGURE 4: *Modulo Two vs. Exclusive OR*

FIRST VALUE	SECOND VALUE	SUM OF VALUES	DIFFERENCE OF VALUES	EXCLUSIVE OR OF VALUES
0	0	0	0	0
0	1	1	1	1
1	0	1	1	1
1	1	0	0	0

Sum and difference tables for modulo two arithmetic are shown in columns three and four. The last column is the corresponding exclusive OR table.

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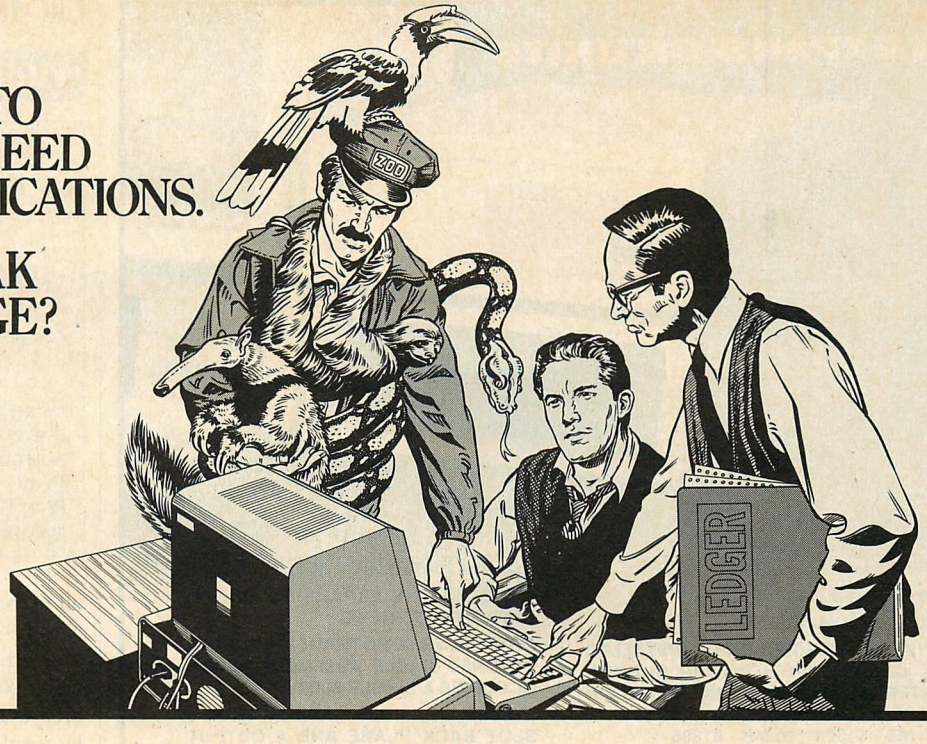

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```
USE ANIMALS
```

selects the database.

```
MODIFY STRUCTURE
```

Move the cursor to the place where you want to insert the new field.

[Ctrl] [N] **adds the new field.**

The new field will be inserted above the cursor position.

[GENDER] [↵] [↵] [1] [↵]

specifies that the new field is titled "GENDER," has the default value of a character field, and is one column wide.

[Ctrl] [W] **ends your input.**

[↵] **confirms that you're satisfied with what you've done.**

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FIGURE 5: *Modulo Two*

```
                1 0 0 0  == x^3 = Q(x)
        ------------------
1 0 1 | 1 0 1 0 0 1
        1 0 1
        -------
          0 0 0
          0 0 0
          -----
            0 0 0
            0 0 0
            -----
              0 0 1  == 1 = R(x)
```

Using modulo two arithmetic, a polynomial $P(x)$ is divided by a polynomial $F(x)$ to obtain the result $Q(x) = X3$ and $R(x) = 1$. Multiplying $P(x)$ by $Q(x)$ and adding $R(x)$ recovers the original $F(x)$.

all errors involving 16 bits or less and about 99.95 percent of errors involving more than 16 bits. The bits do not have to be contiguous. These figures decrease as the message size becomes larger than a few thousand characters. In addition, two of the polynomials are simply a reversed form of those immediately above them.

Since most transmitter chips that support the SDLC/HDLC line-control approach perform the CRC check in hardware, the following discussion is directed toward the CRC-16 polynomial that is used in bisynch protocols.

As an example, suppose the CRC-16 is to be computed for a message consisting of the three characters *ABC*. With the bit reversal on a byte-by-byte basis and the left shift of 16 bits forced by division by a polynomial of degree 16, the division will be set up as shown in figure 6. The remainder of the division is 4521H or binary 0100010100100001.

The thought of computing the remainder of a 2,000-character message is a formidable one indeed. Writing a program subroutine to perform such a computation is no small matter either. If such a program did exist, the computational pressure would be intense on the engine to produce CRCs with all the bit selection shifting and exclusive ORing that is involved.

CRC HARDWARE

Because CRC approaches existed before microprocessors, CRC computation was usually accomplished in hardware. Figure 7 is a representation of the hardware circuitry necessary to produce CRC-16 CRCs. A characteristic of hardware CRCs was their serial nature: data could be presented to the hardware generator bit by bit as each bit became available, and the generation was thus fast and almost transparent. Reducing

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the complex polynomial algebra to a serial process is an important ingredient in the programs that follow.

In figure 7, the CRC register is initialized to 0 for every message, and the first data byte is placed in the data register. The low-order bits of both registers are exclusive ORed together to produce an intermediate bit value of either 0 or 1. The CRC register is then shifted right one bit position.

During the shift, the intermediate bit value is also exclusive ORed with bits 15 and 2 of the CRC register. The results of these operations are then placed in positions 14 and 1, respectively. The intermediate bit value is placed in CRC register bit position 16. Finally, the data register is shifted right one position in order to present the next bit for processing.

When all the data bits in the data register have been processed, another byte is placed in the register and processed in a similar manner. The data bits are naturally processed in reverse order on a byte-by-byte basis, so bit reversal is not a problem. In addition, the polynomial is applied to every message data bit so the user does not have to provide this process with 16 zero bits for padding. The CRC register is arranged so that it can be right-shifted as a unit for proper transmission.

Table 2 illustrates the process of shifting a byte through a CRC-16 generator by hand. The data byte is binary 00000001. When computing the CRC by hand, the user must perform the necessary bit reversal and bit padding of the dividend value. The intermediate CRC register values correspond to the intermediate exclusive OR results provided at each step of the division process, though the values are in reverse bit-order. The remainder is equal to the value that is left in the CRC register. This value is subsequently transmitted and processed as though it were a single value within two data bytes. Note that if the receiving station has the same CRC value in its CRC register (as it would on a successful transmission), it will receive the low-order CRC byte first. Thus, the intermediate bit value produced by the exclusive ORing process during the receipt of the inbound CRC will always be a zero bit.

Similarly, the intermediate values produced by processing the high-order byte of the CRC should always yield an intermediate value of binary 0 at each step. Thus, when the receiving station has completed processing the incoming CRC bytes, a zero value should always be in the receiving station's CRC regis-

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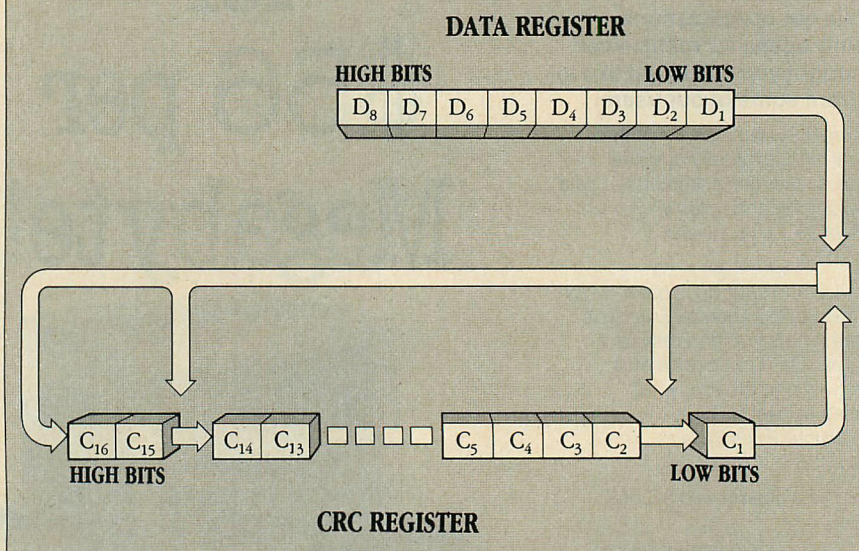
FIGURE 6: *CRC-16 Division*

```
A = 01000001 → 100000010
B = 01000010 → 010000010
C = 01000011 → 110000010

1 10000000 00000100 | 100000010 010000010 110000010 00000000 00000000
                      A         B         C         16 zeros
```

The above division is set up to compute the CRC-16 for a message consisting of the three characters, *ABC*. Bit reversal is on a byte-by-byte basis and the left shift of 16 bits is forced by division by a polynomial of degree 16.

FIGURE 7: *CRC Hardware Circuitry*



CRC computation was formerly accomplished in hardware with circuitry like that shown above for CRC-16 computation. CRC hardware was characterized by its serial nature; generation was thus fast and almost transparent.

ter. This is the test for a successful transmission and corresponds to the observation that there should be no remainder because

$$P(x) * Q(x) = F(x) - R(x)$$
$$= F(x) \text{ exclusive OR } R(x)$$
$$= F(x) + R(x)$$

$F(x)$ is the message polynomial multiplied by X^{16}. In other words, transmitting the CRC and processing it as part of the inbound message is equivalent to adding it to a message that has been right-shifted 16 bits, resulting in an evenly divisible polynomial.

Unfortunately, the programming to achieve this approach is no faster or easier than the methods described earlier. An approach is needed that is fast and easy to code in many languages.

Suppose the user wants to calculate the CRC of an arbitrary byte for an arbitrary intermediate value of the CRC register. Assume the layout in figure 8.

Using the same procedure as outlined above, the user can apply the arbitrary byte to the arbitrary CRC value. As before, D1 and C1 are exclusive ORed together. The result is exclusive ORed to bits C15 and C2 as they shift to the left, and the result of the exclusive ORing D1 and C1 is placed in C16. The data byte and CRC register now look like figure 9. The value of the CRC bit position is the exclusive OR of all the values in the corresponding column. After eight shifts, elimination of canceling instances of the same bits involved in a bit position's exclusive OR calculation, and value rearrangement, the data byte and CRC register look like figure 10.

This clearly indicates that the new value of the CRC is computable from the initial values of the data byte and

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the CRC. Specifically, if an intermediate byte value *V* is created that is the exclusive OR of the low-order byte of the existing CRC and the new data byte, then the new CRC can be created by right-shifting (with zero fill in the high-order positions) the existing CRC eight bits and exclusive ORing a value that can be derived from the various bits of *V*.

Since *V* can have only 256 values, it is possible to build a table in advance that holds the 256 unsigned integer values. Then, the value that corresponds to a particular value of *V* can be quickly located using *V* as an index.

Using this approach, the CRC can be redescribed as shown in figure 11, where *V*1 is the low-order bit of *V*, *V*2 is the next-to-low-order bit of *V*, etc.

The CRC algorithm now becomes:

1. At the beginning of each message, set the CRC to 0.
2. Fetch the first byte of the message.
3. Exclusive OR the fetched byte with the low-order byte of the CRC to obtain a byte *V*.
4. Right-shift CRC eight bits with the high-order bits being zero-filled.
5. Using *V* as an index, fetch a 16-bit unsigned integer value from the CRC table and exclusive OR it to the shifted CRC.
6. The result of the exclusive OR operation is the new value of the CRC.
7. If any more unprocessed bytes are left in the message, fetch the next unprocessed byte and go to step 3.
8. The CRC should be transmitted low-order byte first.

Listing 1 is a C program that computes the CRC table and shows how to use it. The first CRC computation is on the hexadecimal value 100H, which produces a CRC of 9001H. The second example is for 0100H, followed by its byte-wise reversed 0190H. In this case, the CRC is 0 as it should be. The third example illustrates that a string's CRC calculation should not include the terminating NULL character.

This process is implemented in other languages, such as BASIC (listing 2). The table was created by running the C program with I/O redirection. Also, fidding with the high-order bit of the CRC is necessary because BASIC has no provision for unsigned integers, which causes problems with the modulus and integer division required to separate the two bytes of the CRC.

ALGORITHM PERFORMANCE

XMODEM takes about .9 seconds on a PC to compute its checksum for a 128-character data string under interpreted BASIC, while the CRC-16 approach takes

FIGURE 8: *Starting Configuration*

						HIGH			LOW
DATA BYTE:						D8	D7	D6	D5	D4	D3	D2	D1
HIGH						CRC			LOW
C16	C15	C14	C13	C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1

This layout is a starting configuration for CRC generation of an arbitrary byte.

FIGURE 9: *CRC Generator after One Shift*

DATA BYTE:								X	D8	D7	D6	D5	D4	D3	D2
								CRC							
0	C16	C15	C14	C13	C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2
D1		D1													D1
C1		C1													C1

After shifting left one position, the CRC generator of figure 8 changes to the above.

FIGURE 10: *CRC Generator after Eight Shifts*

DATA BYTE:								X	X	X	X	X	X	X	X
								CRC							
0	0	0	0	0	0	0	0	C16	C15	C14	C13	C12	C11	C10	C9
D1	D1	D7	D6	D5	D4	D3	D2	D1	D1						D1
C1	C1	C7	C6	C5	C4	C3	C2	C1	C1						C1
D2	D2	D8	D7	D6	D5	D4	D3	D2							D2
C2	C2	C8	C7	C6	C5	C4	C3	C2							C2
D3	D3														D3
C3	C3														C3
D4	D4														D4
C4	C4														C4
D5	D5														D5
C5	C5														C5
D6	D6														D6
C6	C6														C6
D7	D7														D7
C7	C7														C7
D8															D8
C8															C8

After eight shifts, duplicated bits in a given column have been eliminated.

FIGURE 11: *Reduction to Intermediate Values*

								CRC							
0	0	0	0	0	0	0	0	C16	C15	C14	C13	C12	C11	C10	C9
V1	V1	V7	V6	V5	V4	V3	V2	V1	V1						V1
V2	V2	V8	V7	V6	V5	V4	V3	V2							V2
V3	V3														V3
V4	V4														V4
V5	V5														V5
V6	V6														V6
V7	V7														V7
V8															V8

The CRC is redescribed with V1 as the low-order bit of V, etc.

TABLE 1: *Polynomials for CRC and SDLC/HDLC*

POLYNOMIAL	POLYNOMIAL NAME
$x^{16} + x^{15} + x^2 + 1$	CRC-16
$x^{16} + x^{14} + x^{+} 1$	CRC-16 (reverse)
$x^{16} + x^{12} + x^5 + 1$	SDLC/HDLC
$x^{16} + x^{11} + x^4 + 1$	SDLC/HDLC (reverse)

CRC-16 and SDLC/HDLC are the most commonly used CRC polynomials on 8-bit data. The use of a divisor polynomial of degree 16 results in a 16-bit remainder.

TABLE 2: *CRC Generation*

RESULT AFTER SHIFT	DATA AND CRC	INTERMEDIATE VALUE
START	Data = 0000000 1 CRC = 00 0000000000000 0	1
1	Data = X000000 0 CRC = 10 1000000000000 1	1
2	Data = XX00000 0 CRC = 11 1100000000000 1	1
3	Data = XXX0000 0 CRC = 11 0110000000000 1	1
4	Data = XXXX000 0 CRC = 11 0011000000000 1	1
5	Data = XXXXX00 0 CRC = 11 0001100000000 1	1
6	Data = XXXXXX0 0 CRC = 11 0000110000000 1	1
7	Data = XXXXXXX 0 CRC = 11 0000011000000 1	1
8	Data = XXXXXXX X Final CRC = 11 0000001100000 1	Cannot be determined until the next data byte is loaded into the data register.

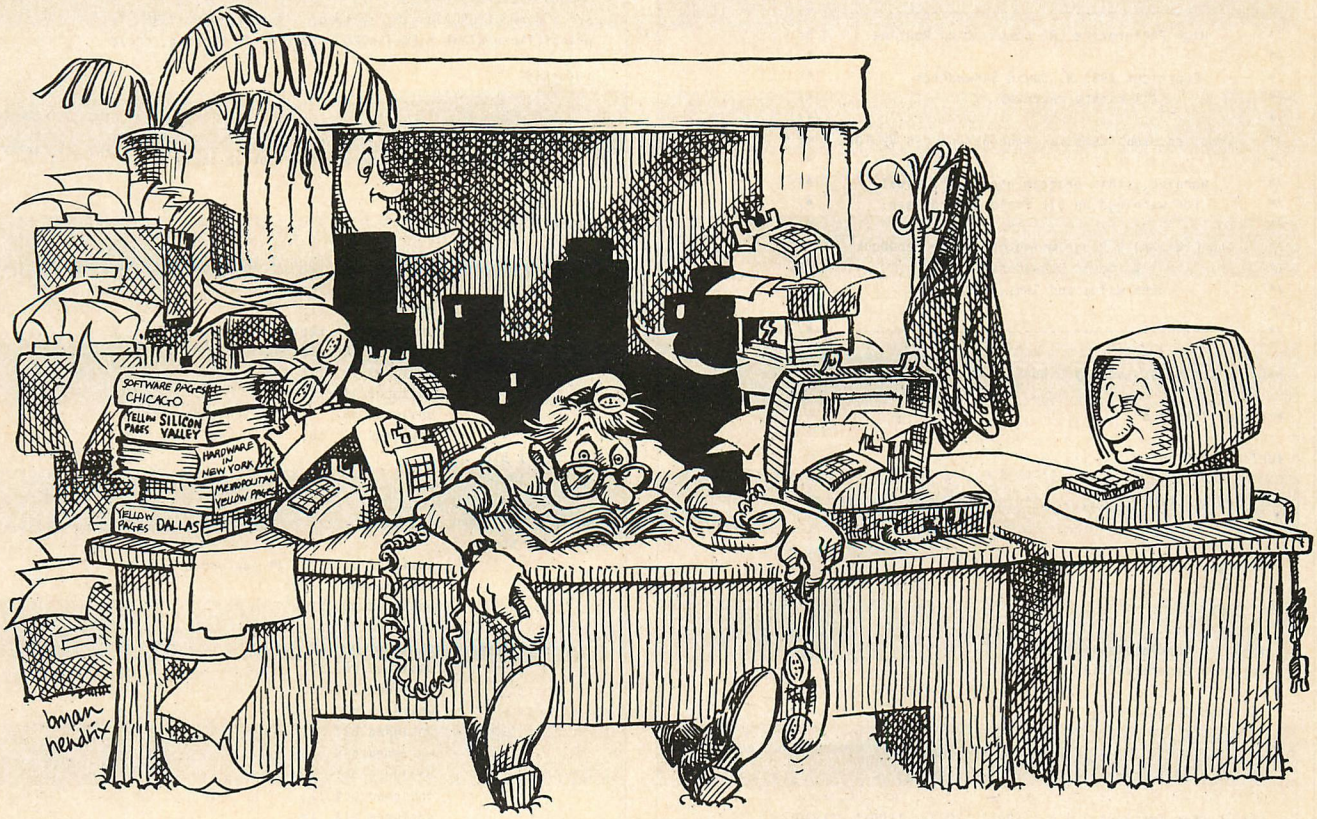
A data byte, binary 00000001, is shifted through a CRC-16 generator by hand. The user must perform bit reversal and bit padding of the dividend value.

about 4.6 seconds. At first glance, this appears a stiff price to pay for enhanced data integrity. However, the calculation of the CRC can be overlapped with the inbound and outbound transmissions under BASIC, recovering some of the lost time. In addition, when compiled, the algorithm runs approximately 50 times faster, reducing the concern substantially, as would assembly language and C approaches. Finally, on a noisy line, the CRC-16 algorithm could be more productive because of its superior error-detection capability.

The CRC-16 is an excellent CRC calculation polynomial. However, statistical analysis shows that the SDLC/HDLC polynomial is even better. The table-look method described here demonstrates that the same table development process is applicable to any CRC polynomial and that only the pattern of bits applied from the byte *V* vary.

Users therefore have no reason to stick with simple CRC calculation procedures when the very best are within reach. Perhaps the industry standards someday will shift to the more effective CRC polynomial calculation procedures.

W. David Schwaderer is a member of the Experimental Office Systems Department in IBM's San Jose Research Division Laboratory. He has written four telecommunication products sold internationally by IBM and is the author of Digital Communications Programming on the IBM PC *(Wiley Press, 1984).*



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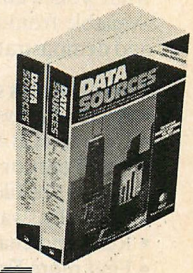

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LISTING 1: CRC.C86

```
/*-------------------------------------------------------*/
/*       High Performance CRC Computation Routine        */
/*                                                       */
/*        Copyright 1985 W. David Schwaderer             */
/*             All rights reserved                       */
/*                                                       */
/*    Compiler used: Computer Innovations C86 V2.10A     */
/*                                                       */
/*       Warning...this program uses bit fields!         */
/*        For warnings on bit field hazards see:         */
/*                                                       */
/*    The C Wizard's Programming Reference Handbook      */
/*              W. David Schwaderer                      */
/*           John Wiley and Sons, 1985                   */
/*                                                       */
/*-------------------------------------------------------*/

watch bit fields...see my C book... */

#include "stdio.h"

#define VOID int

unsigned crc_table[256];     /*   globally accessible  */


main(argc, argv)
int   argc;
char *argv[];
{
  VOID     GenerateTable();
  unsigned GenerateCRC();

  unsigned length, crc;

                          /* crc = 0x9001 */
  static char TestArray1[] = {'\001', '\000'};

  static char TestArray2[] = {'\001','\000', '\001', '\220'};
                           /* bytewise      bytewise */
                           /* unreversed    reversed */

  static char TestMsg[] = "This is a test message.";

  GenerateTable();              /* fill in the crc_table  */

  PrintTable();                 /* display the table      */

  length = sizeof(TestArray1);
  crc = GenerateCRC(length, TestArray1); /* calculate CRC */
  printf("\n\n\nTestArray1 CRC = 0x%04x", crc);

  length = sizeof(TestArray2);
  crc = GenerateCRC(length, TestArray2); /* calculate CRC */
  printf("\n\n\nTestArray2 CRC = 0x%04x", crc);

  length = sizeof(TestMsg) - 1; /* avoid terminating NUL  */
  crc = GenerateCRC(length, TestMsg); /* calculate a CRC  */
  printf("\n\n\nText = [%s]\nCRC = %04x\n\n", TestMsg, crc);

  return(0);

}

VOID GenerateTable()   /* generate the look-up table */
{
  int temp;
  union { int i;
          struct {
                    unsigned i1  :1;  /* low order bit  */
                    unsigned i2  :1;
                    unsigned i3  :1;
                    unsigned i4  :1;
                    unsigned i5  :1;
                    unsigned i6  :1;
                    unsigned i7  :1;
                    unsigned i8  :1;  /* high order bit */
                    unsigned     :8;  /* unused         */
                  } Bit;
        } iUn;

  union {  unsigned int  Entry;
           struct {
                    unsigned b1  :1;  /* low order bit  */
                    unsigned b2  :1;
                    unsigned b3  :1;
                    unsigned b4  :1;
                    unsigned b5  :1;
                    unsigned b6  :1;
                    unsigned b7  :1;
                    unsigned b8  :1;
                    unsigned b9  :1;
                    unsigned b10 :1;
                    unsigned b11 :1;
                    unsigned b12 :1;
                    unsigned b13 :1;
                    unsigned b14 :1;
                    unsigned b15 :1;
                    unsigned b16 :1;  /* high order bit */
                  } EntryBit;
        } EntryUn;

  for (iUn.i = 0; iUn.i < 256; iUn.i++) {

    EntryUn.Entry = 0; /* bits 2 thru 6 zeroed out now */

    temp = (iUn.Bit.i7 ^ iUn.Bit.i6 ^ iUn.Bit.i5 ^
            iUn.Bit.i4 ^ iUn.Bit.i3 ^ iUn.Bit.i2 ^
            iUn.Bit.i1);

    EntryUn.EntryBit.b16 = (iUn.Bit.i8 ^ temp);
    EntryUn.EntryBit.b15 = (temp);
```

```
    EntryUn.EntryBit.b14 = (iUn.Bit.i8 ^ iUn.Bit.i7);
    EntryUn.EntryBit.b13 = (iUn.Bit.i7 ^ iUn.Bit.i6);
    EntryUn.EntryBit.b12 = (iUn.Bit.i6 ^ iUn.Bit.i5);
    EntryUn.EntryBit.b11 = (iUn.Bit.i5 ^ iUn.Bit.i4);
    EntryUn.EntryBit.b10 = (iUn.Bit.i4 ^ iUn.Bit.i3);
    EntryUn.EntryBit.b9  = (iUn.Bit.i3 ^ iUn.Bit.i2);
    EntryUn.EntryBit.b8  = (iUn.Bit.i2 ^ iUn.Bit.i1);
    EntryUn.EntryBit.b7  = (iUn.Bit.i1);
    EntryUn.EntryBit.b1  = (iUn.Bit.i8 ^ temp);

    crc_table[iUn.i] = EntryUn.Entry;

  }

}

VOID PrintTable()        /* print out the look-up table */
{
  int i;

  for (i = 0; i < 256; i++) {
     if ( !(i % 8) )
       printf("\n %02x  -  %04x", i, crc_table[i]);
     else
       printf("  %04x", crc_table[i]);
  }
}

unsigned GenerateCRC(Length, TextPtr)
  unsigned  Length;
  char      *TextPtr;
{
  int i, index;
  unsigned crc;

  crc = 0;      /* crc starts at zero for each message */

  for (i = 0; i < Length; i++, TextPtr++) {
    index = ( (crc ^ *TextPtr) & 0x00FF);
    crc = ( (crc >> 8) & 0x00FF) ^ crc_table[index];
  }

  return(crc);

}
```

LISTING 2: CRC.BAS

```
1000 ' *-------------------------------------------------------*
1010 ' *          BASIC CRC-16 Calculation routine             *
1020 ' *  Copyright 1985 W. David Schwaderer, All rights reserved *
1030 ' *-------------------------------------------------------*
1040 CLS
1050 DEFINT A-Z : FALSE = 0 : TRUE = NOT FALSE
1060 DIM CRC.TABLE(256)
1070 FOR I = 0 TO 255 : READ CRC.TABLE(I) : NEXT I ' Load up table..
1080 MSG$="This is a test message."
1090 GOSUB 1150
1100 PRINT"The CRC for [";MSG$;"] = &h";HEX$(CRC.HIGH);HEX$(CRC.LOW)
1110 END
1120 ' *-------------------------------------------------------*
1130 ' *        This is the CRC-16 Calculation Routine         *
1140 ' *-------------------------------------------------------*
1150 CRC = 0 ' CRC always starts at zero for each message...
1160 FOR  I = 1 TO LEN(MSG$)
1170     VD = (ASC(MID$(MSG$,I,1))) ' Get the value of the byte
1180     VC = ( CRC AND &HFF ) '      Get low order byte of the CRC
1190     V  = VD XOR VC '             Calculate table index value
1200     IF ((CRC AND &H8000) = 0) THEN BIT.ON = FALSE  ELSE
BIT.ON = TRUE : CRC = (CRC AND &H7FFF)
1210     CRC = ( CRC \ 256) XOR CRC.TABLE(V)
1220     IF (BIT.ON = TRUE) THEN CRC=CRC XOR &H80 'High bit fiddle
1230 NEXT
1240 IF ((CRC AND &H8000) = 0) THEN BIT.ON = FALSE ELSE
BIT.ON = TRUE : CRC = (CRC AND &H7FFF)
1250 CRC.HIGH = ( CRC \ 256) : CRC.LOW = CRC MOD 256
1260 IF (BIT.ON=TRUE) THEN CRC.HIGH=CRC.HIGH XOR &H80 'Hi bit fiddle
1270 RETURN
1280 ' *-------------------------------------------------------*
1290 ' *         This is the 256 entry CRC table               *
1300 ' *-------------------------------------------------------*
1310 DATA &h0000,&hC0C1,&hC181,&h0140,&hC301,&h03C0,&h0280,&hC241
1320 DATA &hC601,&h06C0,&h0780,&hC741,&h0500,&hC5C1,&hC481,&h0440
1330 DATA &hCC01,&h0CC0,&h0D80,&hCD41,&h0F00,&hCFC1,&hCE81,&h0E40
1340 DATA &h0A00,&hCAC1,&hCB81,&h0B40,&hC901,&h09C0,&h0880,&hC841
1350 DATA &hD801,&h18C0,&h1980,&hD941,&h1B00,&hDBC1,&hDA81,&h1A40
1360 DATA &h1E00,&hDEC1,&hDF81,&h1F40,&hDD01,&h1DC0,&h1C80,&hDC41
1370 DATA &h1400,&hD4C1,&hD581,&h1540,&hD701,&h17C0,&h1680,&hD641
1380 DATA &hD201,&h12C0,&h1380,&hD341,&h1100,&hD1C1,&hD081,&h1040
1390 DATA &hF001,&h30C0,&h3180,&hF141,&h3300,&hF3C1,&hF281,&h3240
1400 DATA &h3600,&hF6C1,&hF781,&h3740,&hF501,&h35C0,&h3480,&hF441
1410 DATA &h3C00,&hFCC1,&hFD81,&h3D40,&hFF01,&h3FC0,&h3E80,&hFE41
1420 DATA &hFA01,&h3AC0,&h3B80,&hFB41,&h3900,&hF9C1,&hF881,&h3840
1430 DATA &h2800,&hE8C1,&hE981,&h2940,&hEB01,&h2BC0,&h2A80,&hEA41
1440 DATA &hEE01,&h2EC0,&h2F80,&hEF41,&h2D00,&hEDC1,&hEC81,&h2C40
1450 DATA &hE401,&h24C0,&h2580,&hE541,&h2700,&hE7C1,&hE681,&h2640
1460 DATA &h2200,&hE2C1,&hE381,&h2340,&hE101,&h21C0,&h2080,&hE041
1470 DATA &hA001,&h60C0,&h6180,&hA141,&h6300,&hA3C1,&hA281,&h6240
1480 DATA &h6600,&hA6C1,&hA781,&h6740,&hA501,&h65C0,&h6480,&hA441
1490 DATA &h6C00,&hACC1,&hAD81,&h6D40,&hAF01,&h6FC0,&h6E80,&hAE41
1500 DATA &hAA01,&h6AC0,&h6B80,&hAB41,&h6900,&hA9C1,&hA881,&h6840
1510 DATA &h7800,&hB8C1,&hB981,&h7940,&hBB01,&h7BC0,&h7A80,&hBA41
1520 DATA &hBE01,&h7EC0,&h7F80,&hBF41,&h7D00,&hBDC1,&hBC81,&h7C40
1530 DATA &hB401,&h74C0,&h7580,&hB541,&h7700,&hB7C1,&hB681,&h7640
1540 DATA &h7200,&hB2C1,&hB381,&h7340,&hB101,&h71C0,&h7080,&hB041
1550 DATA &h5000,&h90C1,&h9181,&h5140,&h9301,&h53C0,&h5280,&h9241
1560 DATA &h9601,&h56C0,&h5780,&h9741,&h5500,&h95C1,&h9481,&h5440
1570 DATA &h9C01,&h5CC0,&h5D80,&h9D41,&h5F00,&h9FC1,&h9E81,&h5E40
1580 DATA &h5A00,&h9AC1,&h9B81,&h5B40,&h9901,&h59C0,&h5880,&h9841
1590 DATA &h8801,&h48C0,&h4980,&h8941,&h4B00,&h8BC1,&h8A81,&h4A40
1600 DATA &h4E00,&h8EC1,&h8F81,&h4F40,&h8D01,&h4DC0,&h4C80,&h8C41
1610 DATA &h4400,&h84C1,&h8581,&h4540,&h8701,&h47C0,&h4680,&h8641
1620 DATA &h8201,&h42C0,&h4380,&h8341,&h4100,&h81C1,&h8081,&h4040
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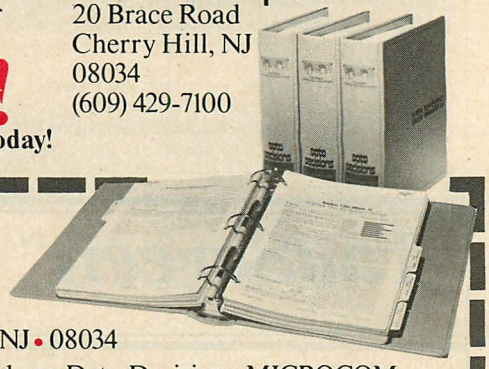

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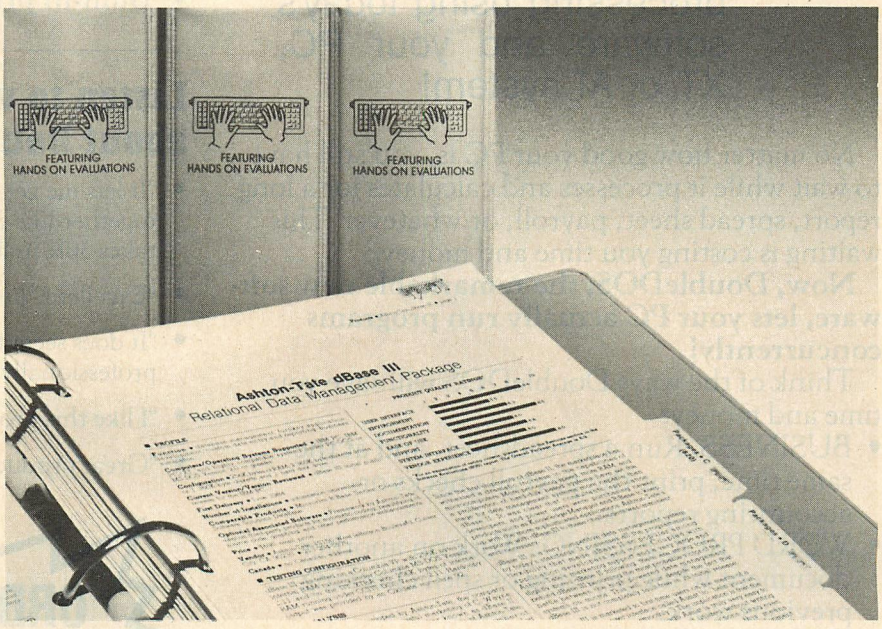

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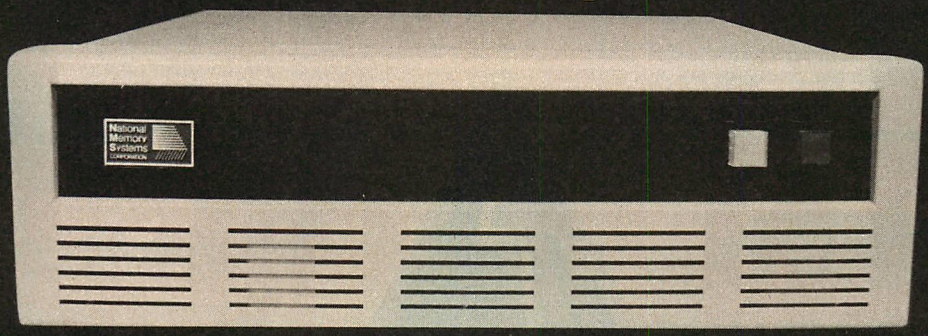

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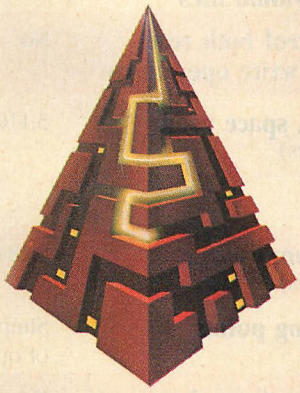

ARTHUR A. GLECKLER

One of the most important improvements made to PC-DOS in version 2.0 was the addition of a hierarchical directory system. It was, however, a mixed blessing: from both a programming and utilization point of view, file access and manipulation became more complex. Most operating systems for larger computers have built-in facilities for dealing with this complexity. PC-DOS added only one: the PATH command. Compared with the more sophisticated capabilities of traditional operating systems, PC-DOS is severely restricted.

File-search utilities are enhancements to PC-DOS that provide some of the directory-management features, such as aliases and search rules, found on larger computer systems. They are designed to enable file location without giving explicit path names, prevent unnecessary duplication of files, and increase the efficiency of the tree-structured directory system.

Many problems can arise in using PC-DOS's directory system. Some programs cannot use path names at all, and therefore are limited to accessing files only in the current directory. To overcome this problem, the user must ensure that all data files are in the current directory when the program is run. Other programs can access data files with a user-supplied path name, but require that system files (overlays, help files, and so forth) be in the current directory. The user either must use the program in one directory, or make copies of the system files in every directory in which the program will be used. The following are three file-search utilities, each of which approaches these problems from a different perspective. (Table 1 lists their features.)

FilePath, from SDA Associates, provides a search list to be used whenever a file that lacks a path specifier cannot be found in the current directory. When a file open request is made to PC-DOS, FilePath looks at the path name that was

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given. If a path specifier was given (for example, \WORKING\DATA.FIL), FilePath simply hands the path name to DOS to be processed as if FilePath had never intervened. If a path name was given without a path specifier (for example, DATA.FIL), FilePath searches the current directory for the requested file (just as DOS normally does).

If the file is found, the file open request returns as usual. If no matching file is found, FilePath searches the paths in its search list, in order, for the requested file. If the file is found in one of these paths, FilePath returns a handle for the file, but does not change the path name. The calling program "thinks" it found the file in the current directory, but is actually accessing a file in another directory. If none of the paths in the search list contains the file, a "file not found" error signal is returned instead of a file handle.

FilePath is most conveniently invoked from the AUTOEXEC.BAT file. Its operation is completely transparent to programs and, once installed, it requires no special attention. FilePath is almost identical in function and operation to the DOS PATH function; its command syntax is as follows:

```
FP Path1 [/T] [;Path2] [/T] . . . [/L=n]
```

where the Paths are those to be searched, in order, when a file is not found in the current directory. The T option, placed after any path, tells FilePath to search that path and any subdirectories under it. The L option defines the maximum number (n) of directory levels in the entire tree structure, including the root directory, to be searched. Wildcard characters are acceptable in path names.

Users of the PATH function may have been victimized by "open-drive-door syndrome," where

```
PATH A:\; B:\
```

has been used to define a search list, and the drive door is open when B: is searched for a program. This results in the "Abort, Retry, Ignore?" message from DOS, rather than the less dangerous "Bad command or file name."

FilePath handles the same problem by skipping paths in its search list that return disk errors. So, even when

```
FP A:\; B:\; C:\
```

has been used to define a search list, FilePath will have no problems searching for a file, whether or not the drive doors on A: or B: are open.

FilePath has one major drawback: while the program handles very well the job of locating existing files, it does not ensure that replacements for those files are written in the same place as the originals were found. If, for example, a program editor is invoked from the root directory, and the programmer loads the file SOURCE.COD (with no path specified), which is located in \PROGRAMS, FilePath may find the file. But, when all modifications to the file have been made and it is saved, the program editor still has the name SOURCE.COD, with no path specifier: it saves the file in the current directory, rather than in \PROGRAMS.

The documentation for FilePath consists of four typeset pages designed to be placed in the PC-DOS *Manual*. It is complete and well written; few instructions are required. Examples of FilePath's operation are included.

SCOUT, from Computer Insights, Inc., includes other features in addition to a file search list. It allows the creation of virtual drives that correspond to directories on physical disk drives. Any directory and its files can be accessed as though they were on a diskette mounted in an imaginary drive.

If \PROG\WORKING\SOURCE were a heavily used subdirectory on the fixed disk, it could be given a corresponding drive name, D:. Executing DIR D: would list all files in \PROG\WORKING\SOURCE. Typing D: would make D: the current drive (in effect, \PROG\WORKING\SOURCE would become the current directory).

No subdirectories are listed on a SCOUT imaginary drive (even if present), and none may be created. Executing MKDIR on a virtual drive always results in "Unable to create directory."

Two primary benefits of SCOUT's imaginary drive function are that first, path specifications can be abbreviated, making it easier to remember where important files are kept, and reducing typing errors; and second, those few programs that still support only the DOS 1.1 file name structure (no path names) will be able to access files in subdirectories. SCOUT protects against the use of FORMAT, CHKDSK, and DISKCOPY on virtual drives by causing these programs to exit harmlessly when applied to a virtual drive.

In addition, SCOUT provides the ability to write-protect a virtual drive. All attempts to write to a protected drive will fail; however, programs still can write to the corresponding directory by using a full path specification, rather than a virtual drive name.

Any virtual drive may be placed on the search list, in a manner similar to that of FilePath, with one minor difference: FilePath uses the search list only if no path specifier is given in a path name. SCOUT, on the other hand, uses

TABLE 1: *Comparison of Features*

	FILEPATH	SCOUT	EASYPATH
Documentation	Good	Good	Excellent
Define aliases for individual files	No	No	Yes
Control both read and write operations	No	No	Yes
Disk space used (bytes)	3,110	7,684	9,509 (EPCNTRL.SYS 3,254) (EP.COM 6,255)
Memory usage (bytes)	3,184	4,720	3,264
Strong points	Simplicity of operation	Fewer keystrokes	Extremely versatile
Preconfigured to handle specific applications programs	No	No	Yes
Price	$24.50	$29.95	$100.00

All three utilities are surprisingly memory-efficient. EasyPath offers the most versatility and control, but is priced considerably higher than the other two.

the search list whenever a file cannot be found, even if a path specifier is part of the path name. In SCOUT, if B:\ is on the search list and the user enters

```
TYPE A:\READ.ME
```

if READ.ME is not present on A:, SCOUT will search B: for the file. FilePath, on the other hand, would not because a path specifier was given.

As with FilePath, SCOUT works by intercepting DOS function calls. It converts virtual drive specifiers to their corresponding path specifiers before passing control to the standard DOS function calls. SCOUT is designed to be invoked from an AUTOEXEC.BAT file, so it must be present on the disk from which the system is booted. The syntax for SCOUT is as follows:

```
SCOUT ImagDrive = PathName /Options
```

where ImagDrive is the imaginary drive to be associated with PathName. Options may include:

D Deactivate search list
A Reactivate search list
R Write-protect ImagDrive
S Add ImagDrive to end of search list

For example,

```
SCOUT D=C: \PROG\PASCAL\TOOLS /S
```

creates the imaginary drive D:, which for most purposes is equivalent to \PROG\PASCAL\TOOLS, and adds it to the search list. Search list order depends on the chronological order in which imaginary drives were added.

SCOUT has no effect on file location; like FilePath, it always saves files that have no path specifiers in the current directory, even if they were found in, and loaded from, another directory. Some may consider this a drawback.

The well-written SCOUT documentation begins with an interesting history of PC-DOS, in which particular attention is paid to the tree-structured directory system. SCOUT's functions are clearly explained and these documentation pages also are designed for inclusion in the PC-DOS manual.

Polygon Software Corporation's EasyPath is a set of four utilities, one of which handles file aliasing. The aliasing utility is made up of two programs: EPCNTRL and EP. EPCNTRL is installed as a device driver and intercepts all DOS file function calls, modifying them as necessary. EP serves as the user interface for EPCNTRL.

EasyPath is installed using the INSTALL program included with the package. INSTALL creates (or modifies) CONFIG.SYS and AUTOEXEC.BAT files

and copies EasyPath onto the boot disk. Special batch files are included for configuring EasyPath for use with many popular application programs, including Lotus' 1-2-3 and Symphony; CROSSTALK XVI by Microstuf; dBASE II, dBASE III, Framework, and Friday! by Ashton-Tate; the Harvard Project Manager by Harvard Systems; the IBM Personal and Professional Editors; MultiMate by Polygon; Multiplan and Word by Microsoft; PFS:File, PFS:Report, and PFS:Write by Software Publishing; VisiCalc by VisiCorp; and WordStar by MicroPro.

EasyPath takes a different approach to solving directory-management problems. Rather than providing a universal search list to be used for all files, EasyPath allows definition of *aliases* for particular file names or groups of file names. Whenever an aliased file name is encountered, EasyPath looks it up in its table of aliases and converts the file name to the corresponding full path name. Aliases take effect even if a file can be found in the current directory.

EasyPath uses the DOS environment, an area used to store a set of strings that is accessible to all applications programs by using DOS function calls. DOS uses the environment to store the current COMSPEC (location of COMMAND.COM) and PATH. EasyPath uses it to store its table of aliases.

A word processing program might require WPP.F to be in the current directory when it is run. By placing

```
SET WPP.F=\PROG\SUPPORT\WPP.F
EP ON
```

in the AUTOEXEC.BAT file, the user ensures that the word processor can find its support file no matter which directory is the current one. The first line above defines an alias for WPP.F; the second line turns on all EasyPath options and activates EPCNTRL. This is an example of EasyPath's file-name-explicit mode of operation; EasyPath can also search the alias table for matching file names (regardless of extension) and for matching extensions (regardless of file name). For example,

```
SET *.OVL=\PROG\SUPPORT\*.OVL
EP ON
```

would cause EasyPath to search for all files with the extension .OVL in the \PROG\SUPPORT directory. This would be useful, for instance, when a program has several overlay files, all with the .OVL extension.

Unlike FilePath and SCOUT, EasyPath changes both where files are searched for and where they are written; files are aliased for both read and write opera-

tions. Consider the problem mentioned earlier with the program editor, where files are to be saved to a common directory for program source files and not in the current directory. This can be done by entering

```
SET *.PAS=\PROG\PASCAL\*.PAS
EP ON
```

This causes all files with the extension .PAS to be read from, and saved to,

SCOUT includes several features in addition to a file search list. It allows the creation of virtual drives that correspond to directories on physical disk drives.

\PROG\PASCAL, and not the current directory, unless a full path name is given. However, it is still possible, using EasyPath, to alias files in such a way that they are read from a directory other than the current one, but are always saved in the current directory.

Files may be aliased by file name, by extension, or both, and wildcard characters are legal in file names; each file may have more than one alias. In this case, the group of aliases serves as a search list, similar to the search lists in FilePath and SCOUT.

EasyPath also allows definition of temporary aliases, which are installed just before a program is executed, and removed immediately upon exiting to DOS. This feature is useful in resolving problems with conflicting aliases (for example, when two different programs use a support file with the same file name), and in preventing the DOS environment from overflowing its maximum allotted space. A batch file can be designed that will add temporary aliases, invoke the desired program, and remove the temporary aliases upon return from the program.

The directories in a file's search list are protected against creating new files, or deleting and renaming files, or both: EasyPath may be told to ignore certain directories in a file's search list when writing the file to disk. These directories will be used only in locating the file for reading. EP is invoked with

EP [ON\|OFF] [/OptionLetters],

where OptionLetters specify any combination of the following options:

? Display a summary of EP command syntax.
?? Display a summary of SET command syntax for EasyPath.
\+ Delete all temporary aliases.
! Display the last file name processed by EasyPath and the alias that was used.
\# Restore the options that were in effect before the last option took effect.
D File names with explicit drive specifiers may be aliased.
P File names with explicit path specifiers may be aliased.

EasyPath allows definition of aliases for file names or groups of file names.

A — (dash) appearing before any OptionLetter turns off that option. EP sends messages to EPCNTRL based on user options. EPCNTRL always checks the DOS environment for its alias table: this is why SET is used to install aliases.

Several utility programs are included in the EasyPath package. EPFILES displays a directory of all files, and optionally includes system, hidden, read-only, archive, and directory files. In addition, EPFILES can modify the attributes of any file or group of files.

The EPSIZE utility will alter COMMAND.COM to change the amount of environment space DOS allocates at boot time. Finally, the program @EP is almost identical to EP, with minor extensions "for advanced users only." These extensions enable @EP to remove EPCNTRL from memory, rather than simply to deactivate it; to ignore aliasing for files that begin with a @ sign; and to handle aliases on file names with the global character ?.

The EasyPath documentation consists of an installation booklet; a user's manual, divided into tutorial and reference sections; and a set of pages for each of the applications programs supported by EasyPath. These pages, as well as the user's manual, are designed to be inserted into the DOS manual. The documentation is excellent, with complete examples on how to use each program, and comprehensive reference information for each utility. In addition, the on-line help provided as part of each utility gives complete information on command line syntax.

A review of the capabilities of these three file-search utilities has shown that each uses a different approach in tackling the same problem; they are similar in that they all integrate well into the existing PC-DOS structure, rather than requiring patches to DOS, and in that their operations are transparent to user programs. This speaks well for PC-DOS; it means that DOS can be extended using simple, standardized methods.

FilePath is the best utility of the three for the novice user. It is easy to install, easy to understand, and results in the fewest side effects. Anyone who can operate the DOS PATH function most likely can operate FilePath—they are essentially the same.

SCOUT has excellent documentation and is particularly useful in dealing with programs that cannot handle path names. It offers the additional, very helpful feature of being able to abbreviate file path names (through its use of virtual drives), thus decreasing the amount of typing necessary to specify a file in a subdirectory.

EasyPath is far more expensive than FilePath or SCOUT, but this is somewhat offset by its ability to control the location of a file on both read and write operations. In addition, EasyPath has the most flexible operation: it uses a different search list for each file, rather than a universal search list for all files. And finally, EasyPath's comprehensive documentation, with installation, tutorial, and reference sections, outdistances that of FilePath or SCOUT.

FilePath: $24.50, plus $2.00 shipping and handling (and $1.60 sales tax for California residents)
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212/563-5487
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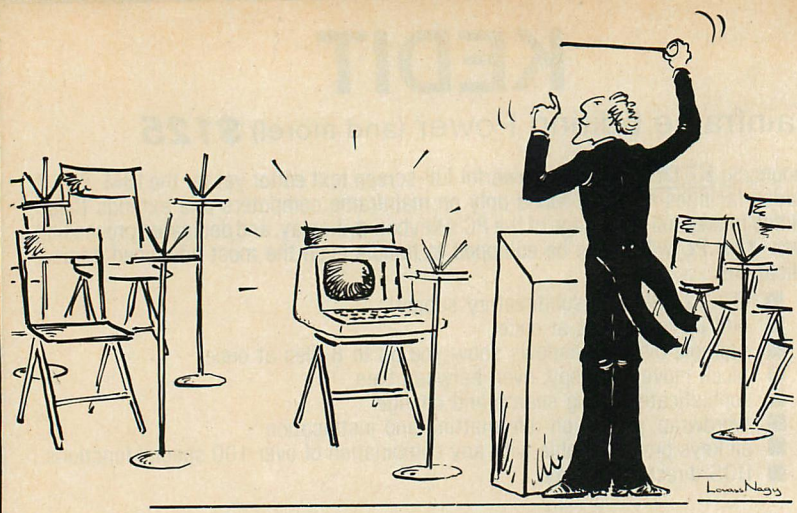
Arthur A. Gleckler is a student at the Massachusetts Institute of Technology and a contributing editor to this magazine.



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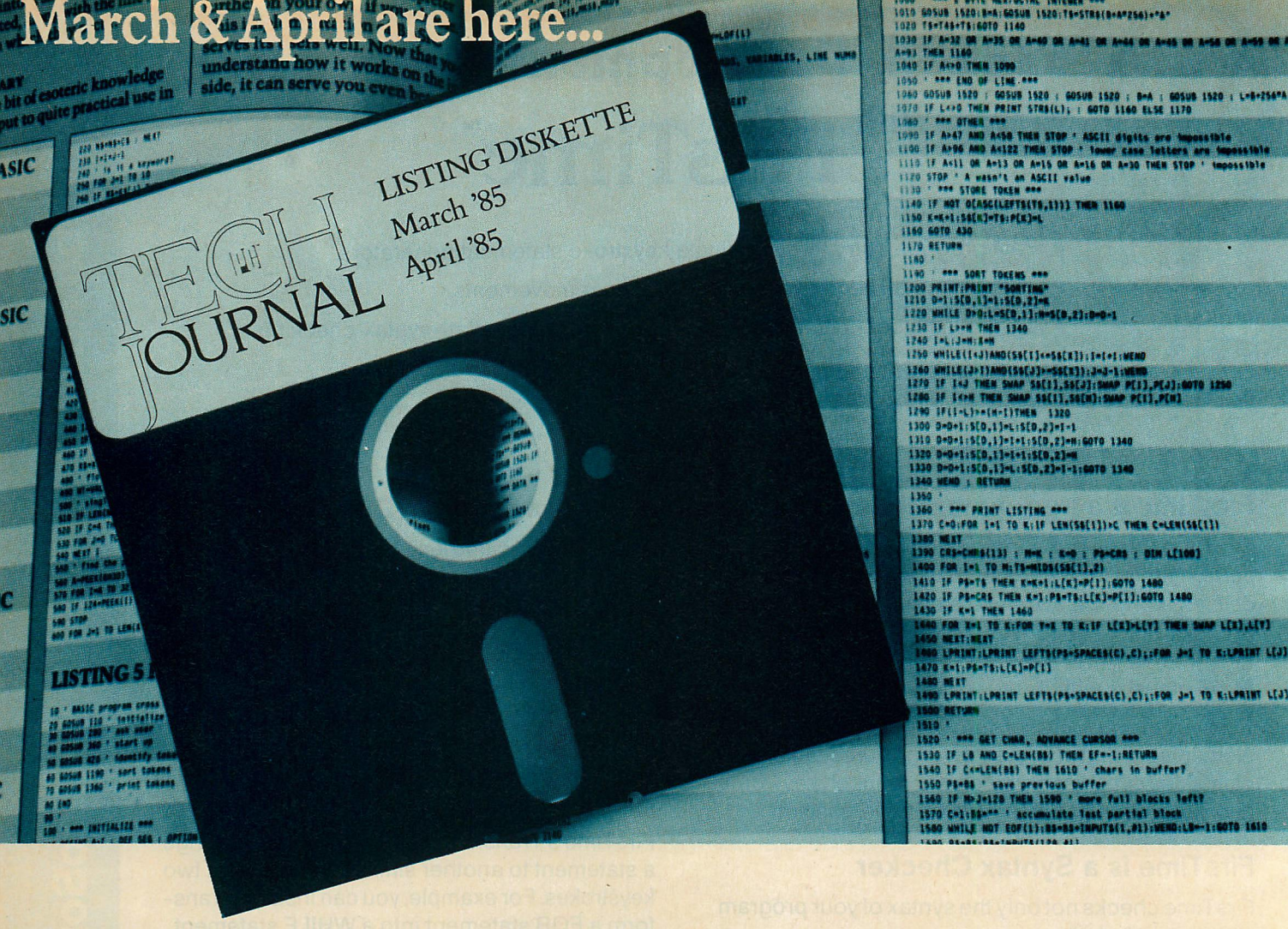

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Screen Composure

New display-management utilities provide capacity and control in screen design.

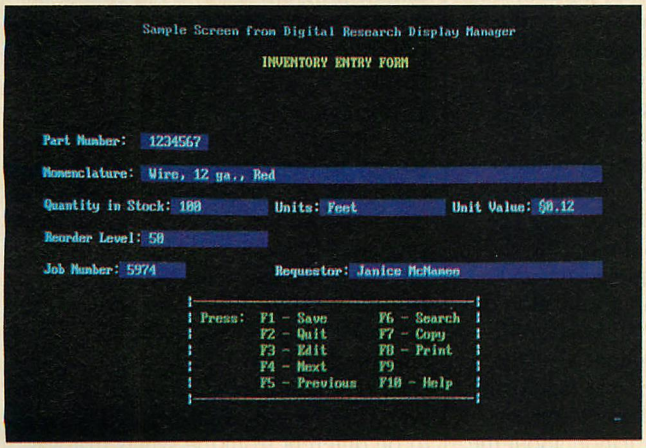
THOMAS McNAMEE

Anyone who has ever designed data entry screens by laying them out on graph paper in an 80-by-25 grid will welcome a new class of utilities called display managers. Display managers do for screen design what word processors do for document composition. These tools enable users to design screens and to specify which fields are to receive user input and which are to display output. They allow the designer full control over display attributes, such as color, and offer automatic validation of input and formatting of output. Two of these utilities are reviewed here: IBM's new entry, the Applications Display Management System (ADMS), and Digital Research's (DR) Display Manager. A comparison of the features offered by each package is presented in table 1.

A short discussion of terminology is probably in order: a *screen* is a single, static display on the CRT that contains text. Typically, screen design calls for laying out the prompt text, input areas, and output areas. The collective term for these areas is fields. A *field* is an area on the screen declared by the designer to have certain characteristics (such as color and size) and a certain function (such as input or output). A display file may contain many screens, and a screen may contain multiple fields. The layout of screens and fields is defined using the program's *editor*. The *runtime package* presents a particular screen, displaying the data in the output fields, and receiving the data typed in the input fields.

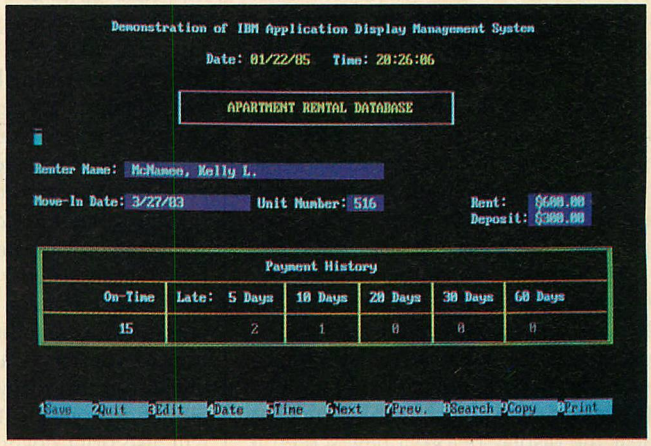
DR's Display Manager is supplied on three disks that contain the four environments that make up the package: terminal set-up, editor, applications programming, and runtime. It is important to remember that Digital Research uses

PHOTO 1: *Sample Display Manager Screen*



This sample screen was created using the Display Manager editor. The field characteristics and validation criteria are specified using control characters similar to WordStar.

PHOTO 2: *Sample ADMS Screen*



Note that ADMS can display continuously updated date and time fields, and supports line drawing characters, border color control, and function key definition and labeling.

a different object module format than the more common IBM and Microsoft products, with no linker or postprocessor that can cross this bridge. Therefore, while Display Manager is a powerful tool, it locks the user into developing applications with the DR product line. And while they are fine products with good support, they are outside of the mainstream of third-party support.

Display Manager works with a monochrome or color monitor. A separate file of control codes must be created with a program called DMSET to define which terminal is being used. These codes are read in by the applications program and are used to initialize a common data area that is linked with the runtime library. This feature permits portability of the application, since only the file containing the control codes needs to be changed to move an application to a new terminal. At present, only the IBM PC is supported, but DMSET appears to have been designed to accept more terminals in the future. Custom code creation is possible according to one of Display Manager's help screens, but it was not permitted from the program's main menu.

As implemented on a color, 80-column monitor, Display Manager will permit all of the normal color options to be displayed, plus blink. The program responds to the IBM arrow keys and the function keys F1 through F10. Any other special key-code detection, such as Ctrl or Alt key combinations, is the responsibility of the programmer.

After its installation by DMSET, the editor is invoked by typing DMED; it provides a rich development environment in which screens can be designed, viewed as they will appear in their application, and saved in a file. The editor must first open the specified display file, which can contain as many as 250 screens. The display file is referenced by file name, and the individual screens are referenced by number. Inside the editor a screen directory is available that displays a descriptive title next to each screen number. The user can edit or delete a screen, open a new display file, renumber all screens, get help, or quit the editing session.

When a screen is first selected for editing, certain global features must be defined, such as the background and text colors. It is possible (although too much might be annoying) to blink the displayed text. The user can opt not to clear the display before a new screen is displayed, permitting screens to overlay one another. In practice, this is useful only for displaying headers or static text since the last screen displayed is the only one that can accept input.

TABLE 1: *Features Comparison*

FEATURE	DISPLAY MANAGER	ADMS
Full-screen editor	Yes	Yes
Color/monochrome support	Yes	Yes
40/80-column display	Yes	Yes
Maximum screens/file	250	30
Maximum fields/screen	250	999
Input validation	By type	By type and value
Output formatting	Yes	No
Screen selection	By number	By name
Field selection	By number	By name
On-line help	Yes	Yes
Common attributes screen	No	Yes
Function key support	F1–F10	Yes
Function key prompt line	No	All
Definable interrupt keys	No	Yes
Intrinsic error messages	No	Yes
Memory-resident screen files	No	Yes
Imbed files	No	Yes
Line drawing characters	No	Yes
Border color control	No	Yes
Runtime support	Function library	Resident handler
Licensing required	No	Yes
Documentation utility	Yes	No
Supported languages	CBASIC (CB86)	IBM BASIC
	PL/1-86	BASIC Compiler
	Pascal MT+86	IBM COBOL
	DR C	IBM FORTRAN
		Assembly language
		IBM Pascal

Both display managers have the basic features that are needed by a user to create data entry screens for applications programs, but ADMS has extended features that save programming time and effort and also improve performance.

The user is then presented with the screen to edit; text is entered the same way as for many text editors. (In fact, many of the editing commands mimic WordStar.) DR's editor does not support line-drawing characters, so boxes and lines must be made using the underscore and bar characters. Field definition is also accomplished with control characters. Each screen may have up to 250 fields, input or output. To add color highlights to a menu, output fields can be declared over existing text. The manual refers to these as *literal* fields; they remain unchanged while the screen is displayed.

Fields are referenced by number and are configured through a display overlay called the *status window*. The status window permits the user to define the foreground and background field colors and any input validation or output formatting that is to occur. The user can designate a definition as the default, so that many similar fields can be defined quickly. Display Manager will also print documentation about the screen for reconstruction if the file is lost. Photo 1 shows a sample screen that was created using Display Manager.

The applications programming environment is the area in which the IBM and DR packages differ the most. IBM's runtime screen manager is a resident program. The applications program communicates with the screen manager through a data control block and a software interrupt. DR has provided a library of functions to initialize the system, manage the screen display, and manage the input and output of field data. This library is linked to the applications program and is independent of the language being used. Currently, the languages that are supported by Display Manager are compiled BASIC, Pascal/MT+86, PL/1-86, and DR C.

The 16 library functions are described in table 2. Examples of how the DISPD (display selected screen) function is invoked in each of the supported languages are shown at the bottom of the table. The examples given in the Display Manager manual are all in compiled BASIC, so translation to other languages takes some experimentation. (A poor description of C was given; the syntax for argument passing turned out to be different from the syntax that was described in the manual.)

The DISPD function highlights a major difference between the two pack-

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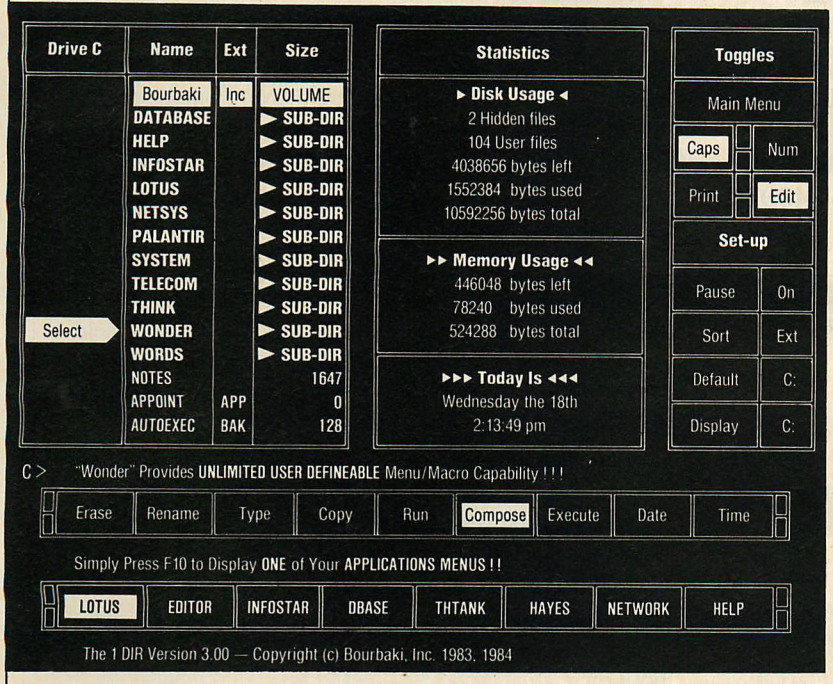

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TABLE 2: *Display Manager Function Library Calls*

INITIALIZATION FUNCTION	
INITDM(INIT$)	Initializes the Display Manager system with codes stored in INIT$
DISPLAY MANAGEMENT	
CLRSCR	Clears the screen
CLSDIS	Closes the current display file
OPNDIS (FILE$)	Opens the display file FILE$ for use in the application
DISPD (SCREEN%)	Retrieves the screen numbered SCREEN% from the current display file and places it on the screen
RETDM	Returns the features available on the runtime terminal
CURS (MODE$)	Sets the cursor on or off, or toggles the current condition, as specified in MODE$
FIELD MANAGEMENT	
ENDF	Returns a value to indicate how data entry for the last field was terminated, can indicate validation failure or that a cursor key or a function key was pressed
RETF	Returns the field position, length, and type
PUTF (DATA$)	Puts the data in DATA$ into the current field
SETF (SET$)	Sets field attributes while the application is running, according to the specifications in SET$
POSF (FIELD%)	Places the cursor in the field numbered FIELD% in the current display
NXTF (POS%)	Places the cursor in the specified field in the current display, permits positioning relative to the current cursor position
RESF (STORE%)	Permits resumption of data entry after an abnormal termination, such as a validation error, STORE% specifies one of eight storage locations that are used to hold the data entered
GETF	Retrieves and validates information from the current field and stores it in a string variable for use in the applications program
UPDF	Similar to GETF, but returns any initial values appearing in the field when the screen is first displayed

SAMPLE CALLING SEQUENCES IN EACH SUPPORTED LANGUAGE

CBASIC	RET_ERR%=DISPD(SCREEN%)
PL/1	ret_err=dispd(screen_number);
PASCAL	ret_err :=dispd(screen_number);
C	ret=dispd(screen);

The applications program invokes the Display Manager functions through subroutine calls to a library linked with the program (see the examples for DISPD at the bottom). The method of passing parameters varies for each language.

ages: IBM uses labels in order to reference screens; DR uses numbers. The IBM approach is highly mnemonic while the DR approach lends itself to a few programming tricks. With the Digital Research product, a help screen can be created with a screen number that is some fixed offset (100, for example) from the screen being displayed. With this capability, a single function can handle both the main screen and the associated help screen when only the main screen number is known. Field referencing by numbers is also a valuable feature to have when a series of prompts needs to be displayed.

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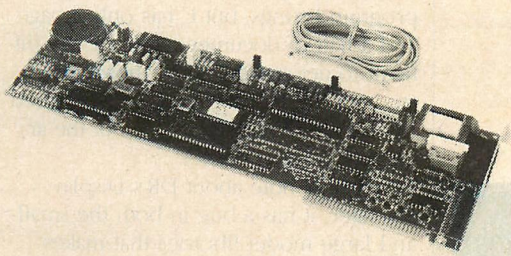

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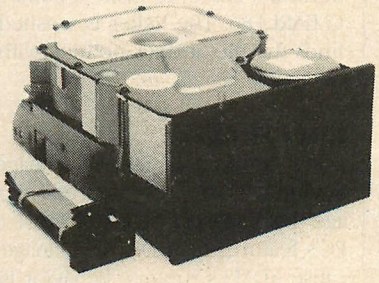

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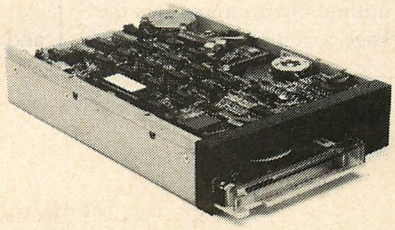

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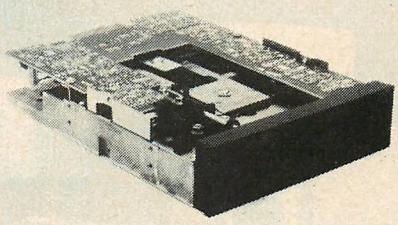

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Display Manager leaves a great deal of the programming up to the user. Input validation, for example, can be set to detect alphabetic, control, integer, or decimal data, but the user must check the input value for correctness. Displaying any error messages resulting from that check is also the responsibility of the user. This arrangement is in sharp contrast to IBM's flexible validation and error-reporting system, which is built into the input routines.

The runtime environment ties the whole package together. To run an application, the terminal control code file is needed, along with the application. The program will read in these codes and send them to the INITDM function, which initializes a common data area shared by the library functions. Then a display file will be needed that contains all the screens created with the editor. Finally, the applications program must generate the appropriate function calls to initialize the system, open the display file, and display a selected screen.

Both the terminal set-up program and the editor have an on-line help feature. This is especially useful in the editor where there are many control key sequences to remember. For validation, formatting, and color codes, however, the manual must be consulted.

The Digital Research manual is written in a rigid top-down style. It possibly contains all the information that is necessary to use this utility with any of the supported languages, although finding a reference to a particular item may be somewhat difficult. The C language support is given little treatment. The other languages have complete sample program listings, but C has only a page and a half of documentation. (It was difficult to get started, and a thorough study of the Pascal section was required in order to understand some of the argument passing rules.)

A final note about DR's Display Manager: it has a bug in both the small and large model libraries that makes them go looking for a system library (CLEARL.L86) that is not needed. Since CLEARL.L86 is a huge file, it is an inconvenience for the floppy disk user to have it and the other required libraries on the disk at the same time. Digital Research has published a fix using IBM DEBUG, but it is available only to subscribers to DR's technical support line. There is, however, a simple way around the bug: create a "do nothing" function, compile it, and use the Digital Research librarian, LIB86, to make a dummy CLEARL.L86. The linker is satisfied if it finds the file; it does nothing with the contents.

IBM's ENTRY

IBM's Applications Display Management System (ADMS) is an impressive package that takes advantage of more of the PC's features than Display Manager. Because ADMS's runtime behavior is controlled by a memory-resident handler, ADM.COM, and because the machine language interface is so clearly defined, ADMS is not limited to those languages specified in table 1. C can certainly be added, as can any language from which a machine call can be made.

Users should note that a license must be obtained to distribute any program using ADM.COM. According to IBM, a $100, one-time fee is charged for unlimited rights to distribute ADM.COM. Digital Research, on the other hand, permits applications programs that are linked with its library to be distributed freely.

ADMS is divided into two major sections: the designer (an editor, ADD.COM) and the manager (ADM.COM and the language inter-

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faces). Basically, the designer is a file-management shell around seven subeditors that handle different areas of screen design. The user can move between the subeditors with one keystroke. The entire editor is an applications program made with ADMS; the editor demonstrates the wide range of capability in the system.

Screen design begins with text entry. All prompts and other messages are entered in the text subeditor. To change the color of the entire screen, the general features subeditor is used. With this subeditor, the color of the background, the text, and the screen border can be controlled. Even the sound of the error beep can be set from 64 to 2,000 Hz. Separate attributes for color and monochrome monitors can be assigned at the same time. Switching from one to the other is accomplished using a function key.

To add color to specific places on the screen, the highlighting subeditor is used. A maximum of 16 combinations of color, intensity, and blinking can be defined and assigned to unused characters on the PC keyboard. The user then moves the cursor into the window in which the screen is displayed and "paints" the areas that are to be highlighted. Fields also can be highlighted using this technique. This independence of highlighting from field definition is unique to the IBM package.

Fields are defined using the fields subeditor. The name, type, length, associated error messages, and validation criteria for each field are specified here. Special function fields provided with ADMS can be used to display the date and time (static or continually updated), the cursor position, or the status of the lock keys. Validation of field input consists of conditionally accepting user input only if it complies with specified rules—that is, a field can be declared character, integer, or decimal. A sample screen is shown in photo 2 (note the date and time displayed at the top).

Besides performing the basic validation of fields according to type, ADMS also permits validation according to value. A range of acceptable values can be established. For example, for an integer field, ADMS could be instructed to accept all integers between 1 and 6 as well as the integer 9, and for a character field, only strings beginning with Kelly, Janice, or Tom might be designated as valid. Character data validation is further enhanced through the use of wildcard characters similar to the PC-DOS * and ? characters—an extremely useful and time-saving feature.

TABLE 3: *Control Block and Variable Table Structure*

CONTROL BLOCK STRUCTURE

```
ioscb       struc
opt         dw          ;ADM options flag
name        db '        ';Screen file name
panid       db '        ;Screen identifier
ibuf        dw          ;Input buffer (in caller's DS)
bleng       dw          ;Length of input buffer
iinbu       dw          ;Resident include buffer
iblen       dw          ;Resident include buf length
errno       db          ;Error number to be issued
iosk        db 4 dup (' ')  ;Depressed interrupt key
iosd        db 8 dup (' ')  ;Caller's description of IOSK
vtabp       dw 0        ;Pointer to caller's variable table
vtabc       dw 0        ;Variable table element count
vtabds      dw 0        ;Alternate DS for variable pointers
cv          db 8 dup (' ')  ;Cursor position (variable name)
cd          dw 0        ;Cursor position (displacement)
            db 3 dup (0)    ;Reserved
iosch       ends
```

OPTION FLAG BIT SETTINGS

Bit 0 – Screen definition source
ON => Screen to be read in from disk
OFF => DS:IOSCB.IBUF points to buffer
DS:IOSCB.BLENG contains length

Bit 1 – Sound audible alarm
ON => Sound 440 HZ alarm when screen is displayed
OFF => Do not sound alarm

Bit 2 – Clear screen when ADM is exited
ON => Clear screen before returning to caller
OFF => Do not clear screen

Bit 3 – Do not display screen or wait for response (this option used internally by the ADM BASIC interface code)
ON => Syntax check input and return control
OFF => Process input screen

Bit 4 – Terminal response processing
ON => Do not wait for operator input
OFF => Wait for operator input

Bit 5 – Redisplay current screen (complement to bit 3 above)
ON => Resubstitute variable fields and redisplay current screen
OFF => Reconstruct screen from input area

Bit 6 – Quiet option
ON => Do not sound any audible alarms while processing the screen
OFF => Issue alarms as needed

Bit 7 – Reserved

Bit 8 – Push/pop imbedded field highlighting
ON => Causes ADM to save and restore the field highlighting table before and after an in-memory include
OFF => Highlighting changes are not reset
NOTE: This option requires additional work storage of 80 bytes for each display line that has highlighting defined in it

Bit 9 – Field substitution bypass
ON => Do not substitute variables into fields
OFF => Substitute variables

Bit 10 – Keyboard purge control
ON => Do not purge buffered keystrokes
OFF => Purge buffered keystrokes

VARIABLE TABLE STRUCTURE

```
vtab        struc
vtabname    db '        ;Variable name
vtabptr     dw          ;Ptr to var (in DS if VTABDS=0)
vtablen     db          ;Variable length
vtabind     db          ;Substitution bypass indicator
vtab        ends
```

To call ADMS, a routine moves the parameters into the control block and issues an int 64H. The variable table is used for passing the input and output data.

When input is found to be invalid, an error message can be issued. These messages are defined in the messages subeditor. They are referenced by number and can be displayed on any line of the screen the user desires.

Function key values can be defined in the function key subeditor. The function keys (F1 through F10), as well as the Shift, Ctrl, and Alt key combinations can be defined. Both a value and a label can be assigned. A line of labels, similar to the one that appears in BASIC on line 25, can be placed anywhere on the screen. When the Shift, Alt, or Ctrl keys are pressed, the line changes to reflect the functions of those keys. Function keys return a string to the program through a variable in the control block (discussed below, along with the variable table structure) and can be used to control program execution.

Interrupt keys, defined in the interrupt key subeditor, return the user to the applications program. The code of the key pressed is returned in a variable in the control block. A total of 20 interrupt keys can be defined.

One difficulty inherent in a product of this sort is the fact that a disk access is required each time a new screen is to be displayed. With ADMS, a screen file can be loaded into memory and remain resident, thereby speeding up the access time for screens. Additionally, most applications have some features that are common to every screen—interrupt keys, function keys, and error messages are shared throughout an application. To avoid having to define these same items each time a new screen is created, the features can be defined once in a screen called the COMMON screen. This screen can be edited like any other; changes to it affect every screen in the display file.

To create a common set of features that extend across screen files, an Imbed file can be created. An Imbed file consists of a display file containing only a COMMON screen. If the features of the Imbed file screen are to be used in an application, its name is specified to the general features subeditor. The function key definition, interrupt keys, and messages in the Imbed file then become part of that screen.

ADMS MANAGER

The manager is a memory-resident handler for displaying screens created with the designer. It must be initialized prior to use and will consume about 28 to 30KB of memory. When the manager is no longer needed, it can be terminated and its memory returned to the system.

The manager provides an interrupt-driven interface between the supplied language interface modules, the screen data structure, and a set of memory-mapped video drivers. Parameters to be passed to ADM are moved into the control block and variable table structures shown in table 3. The BX register is set to the address of the control block, the AL register is set to 0, and interrupt 64H is invoked. Language interface modules are supplied for compiled BASIC, FORTRAN, and Pascal; a special interface is also supplied for interpreted BASIC.

Each interface translates the high-level language data structures into the control block and variable table formats. The data structures are defined in INCLUDE files supplied for each language supported. For assembly language, no interface module is required; the control block and variable table can be accessed directly. However, when designing in assembly language, note that there are a few mistakes in the documentation of the vtab structure. The variable name is shown to be one character long; it is actually eight characters.

ADM.COM can be invoked with several command line switches. The /B switch installs the interpreted BASIC interface used with BASIC or BASICA. Switches are also available to silence the sign-on beep, reserve memory for screen display, and enable or suppress several application functions. Other switches allow the user to select the date format and the decimal point character, thus permitting international use. This capability seems to have been included to allow an older DOS to achieve the same international portability as is permitted in DOS 3.0.

According to IBM's fact sheet, ADM will run on every computer in the PC family, from PC*jr* to the PC/AT, and on every level of DOS, beginning with 1.1. Language support was developed for every IBM-logo language (which explains why C was left out). ADM can run even under TopView, IBM's multitasking operating environment. The source code for a demonstration program is supplied for every language supported. These demonstrations serve as good examples of applications code. ADMS is essentially language-independent; applications developed under interpreted BASIC can be moved to assembly language without having to change the screen file.

A high degree of functionality is achieved through the use of option bits to enable or disable certain screen features. The most impressive demonstration of this functionality is the size of the application's source code. After lines for initialization and comments were subtracted from the demo programs supplied with the package, most of the programs required less than 20 lines of code to implement a highly interactive demonstration. The demo in interpreted BASIC is impressive because screen management occurs at machine-language speed. The demonstration runs at about the same speed in BASIC as in assembly language.

The only shortcomings ADMS has are its lack of a C-language interface and the decidedly fewer number of screens allowed per file. C language support is an attractive part of the Digital Research product, but once the user is committed to the DR Display Manager and C compiler, he is unable to take advantage of some add-on libraries for other C compilers.

ADMS can do anything Display Manager can do; further, it performs many features automatically for which Display Manager requires custom code. Equivalent applications require less coding and testing time with ADMS and are easier to maintain. And, even with the licensing fee added to the initial cost of ADMS, it is still half the price of Display Manager. All in all, the functionality and concept of the IBM Applications Display Management System puts it ahead of anything in its class.

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Thomas McNamee works as a project manager of automatic test equipment systems for ManTech Technical Services located in Alexandria, Virginia. He also has a private microcomputer consulting service.

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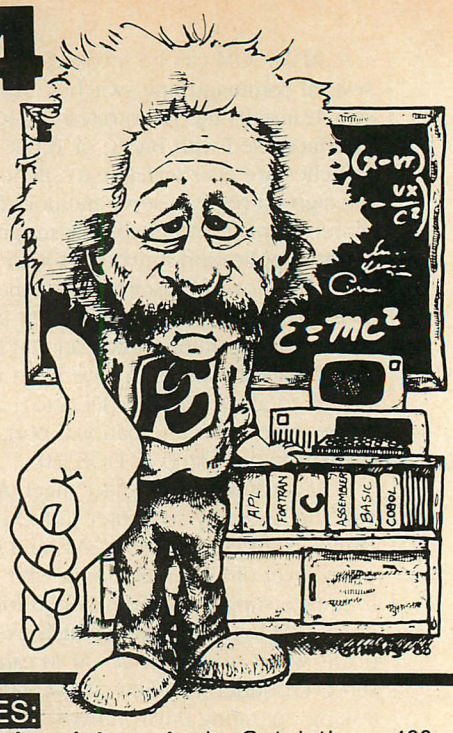

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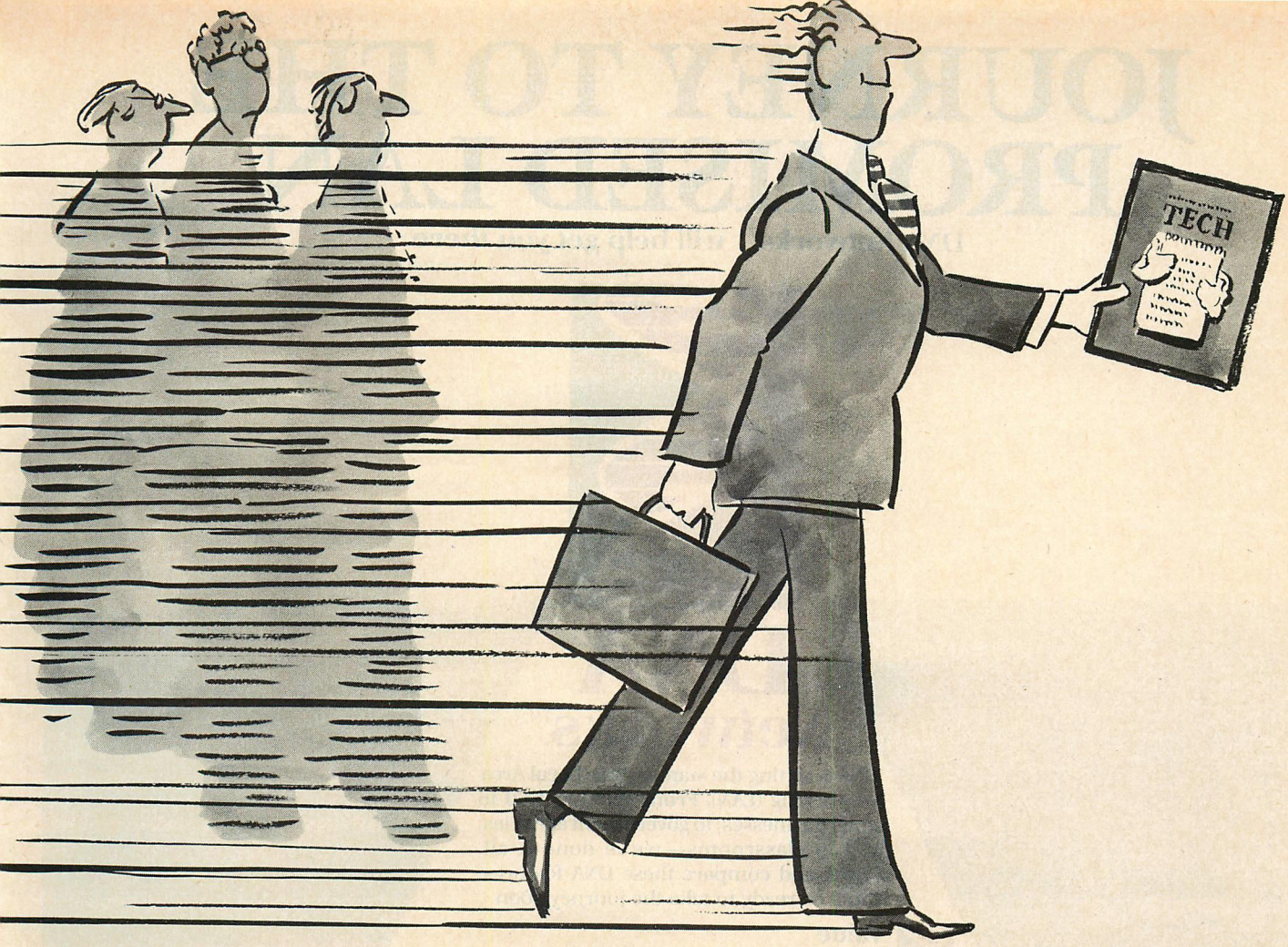

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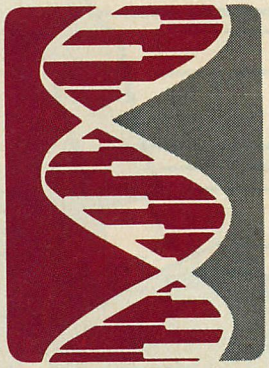

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Searching with Soundex

Commonly used in commercial applications, the Soundex Algorithm can build flexibility into data retrieval systems.

THOMAS W. MADRON

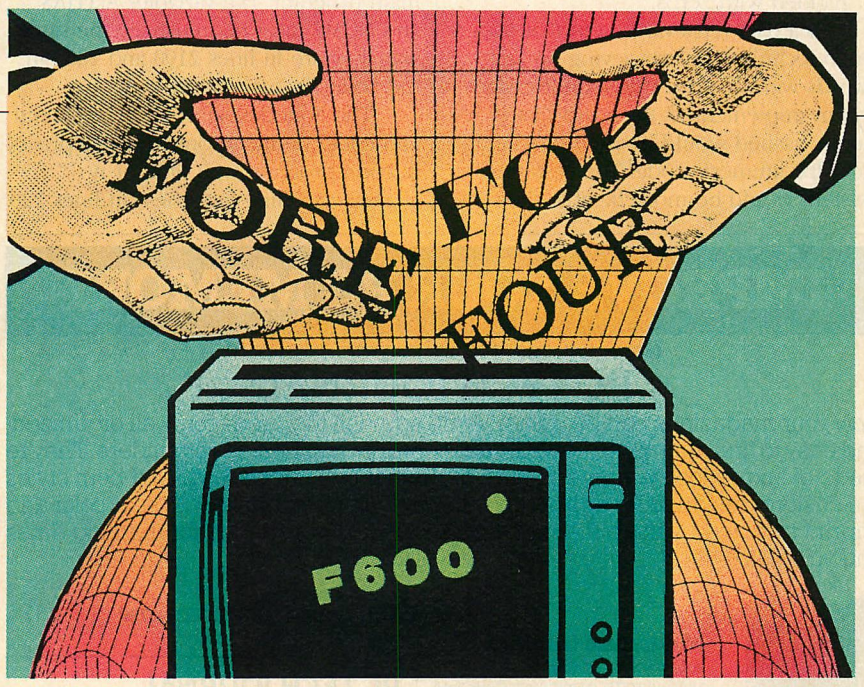


ILLUSTRATION • CHRIS SPOLLEN

It is interesting that some data retrieval programs retrieve not only on a specific key, but also on keys with similar spellings (or sounds). Searches like these can be done in a number of ways; one common method that is in widespread commercial use, particularly where retrieval is based on surnames, is the Soundex Algorithm.

The algorithm itself is not new. In fact, its formulation by Margaret K. Odell and Robert C. Russell predates the computer; it was registered with the U. S. Patent Office in 1918 and again in 1922. The goal was to provide a classification scheme for words that sound alike. In use, the algorithm produces a four-character, alphanumeric code consisting of a letter followed by three digits. Two words that sound alike, even though they have different meanings, will be coded identically or with very close numeric values. In a like manner, words with similar spellings will be coded with identical or close numerical values. The general sort order of the words will be retained owing to the fact that the letter designation is the first letter of the original word.

As an illustration, two words that sound alike, but that are different in meaning, are great and grate; both words code to G630 using the Soundex Algorithm. A more practical example might be in retrieving key words where it would be useful to allow for minor misspellings—with names for instance. The name Madron codes to M365. Two possible misspellings are Madren and Metrin—but these and virtually all misspellings that "sound" like Madron will produce the M365 Soundex code.

In a data file of names and addresses, with a program to retrieve on names, this algorithm would provide a most useful flexibility: the user may enter a name or a close misspelling, and still retrieve the correct record. In a file with many names that have the same Soundex code, a linked list structure can be used to access specific records. Each list is treated as a logical unit, thus retaining the assumption that in a key indexed system each key is unique. See *The Art of Computer Programming, Volume 3, Sorting and Searching* (Addison-Wesley, 1973, p. 392).

The rules used in constructing a program using the Soundex Algorithm are as follows:

- The first letter of the word is re-

moved and saved. That letter becomes the first character of the resulting Soundex code.
- If a double letter is used in a word, such as the "oo" in soon, then the second letter is ignored.
- All letters are converted to upper case before coding.
- Any occurrence of the letters A, E, H, I, O, U, W, and Y (all vowels plus H, W, and Y) are ignored.
- Occurrences of B, F, P, and V are coded 1.
- Occurrences of C, G, J, K, Q, S, X, and Z are coded 2.
- Occurrences of D or T are coded 3.
- Any occurrence of L is coded 4.
- Occurrences of M or N are coded 5.
- Any occurrence of R is coded 6.
- If a numeric value larger than three digits occurs, the entire code is truncated to four characters (the beginning letter followed by three digits).
- If a numeric code is less than three digits, the resulting number is right-padded with zeros.

If a data retrieval system that uses a hash technique for retrieving on key words were to have the Soundex Algorithm implemented, the word that is actually hashed would be the four-character alphanumeric code. The resulting system would be more flexible than one that required a specific and correctly spelled key. Such a system would also have to provide a linked list structure to provide for collisions since Soundex was devised to ensure that the same code would occur under varying conditions based on the way characters sound when pronounced aloud.

Listing 1 is a sample program that calculates and displays a Soundex code. Though written in BASIC, the program is highly structured; however, it could be implemented in any language. The program comprises a main program and a series of subroutines. Homogeneous groups of program lines are set apart as *segments* within a subroutine or main program. (The adoption of *segment* for this purpose is arbitrary and used only to clarify the coding.) Conversion from an upper case alphabetic character to the appropriate numeric code is accomplished through a table lookup technique implemented in the line function FNSX$ at line 230 in the main program. The variables ALPHA$ and NUM$ must be initialized the same way they are in lines 2190 and 2200 in the Soundex subroutine.

The Soundex subroutine is general and could be incorporated into a production program with little or no change. Two line functions (in lines 220 and 225) might also be useful in other programs. The first, FNCE$() centers a string in a line LL characters long, while the second, FNUL$(), converts an alphabetic character to its upper case equivalent. The uppercase conversion program may not be self-explanatory, but it worked well with versions of Microsoft BASIC run under TRSDOS, CP/M-80, MS-DOS, and PC-DOS:

```
DEF FNUL$(A$)=CHR$(ASC(A$)
   +32*(95<ASC(A$)))
```

The decimal values of the capital letters A through Z are 65 to 90, respectively. If the parenthetical expression (95<ASC(A$)) is true, then the result is −1, if not, it is 0. That is, if the decimal ASCII value of the character contained in A$ is greater than 95 (which would mean that it is a lower case character), then the expression 32 * −1 = −32. Each lower case character has a decimal ASCII value that is 32 greater than its corresponding upper case character (A=65; a=97, for example). When −32 is added to 97 (a) the result is 65 (A). If the character in A$ has a value that is less than or equal to 95, the expression evaluates to 0, which is added to the decimal ASCII value of the character in A$. (65 + 0, for example, remains 65.)

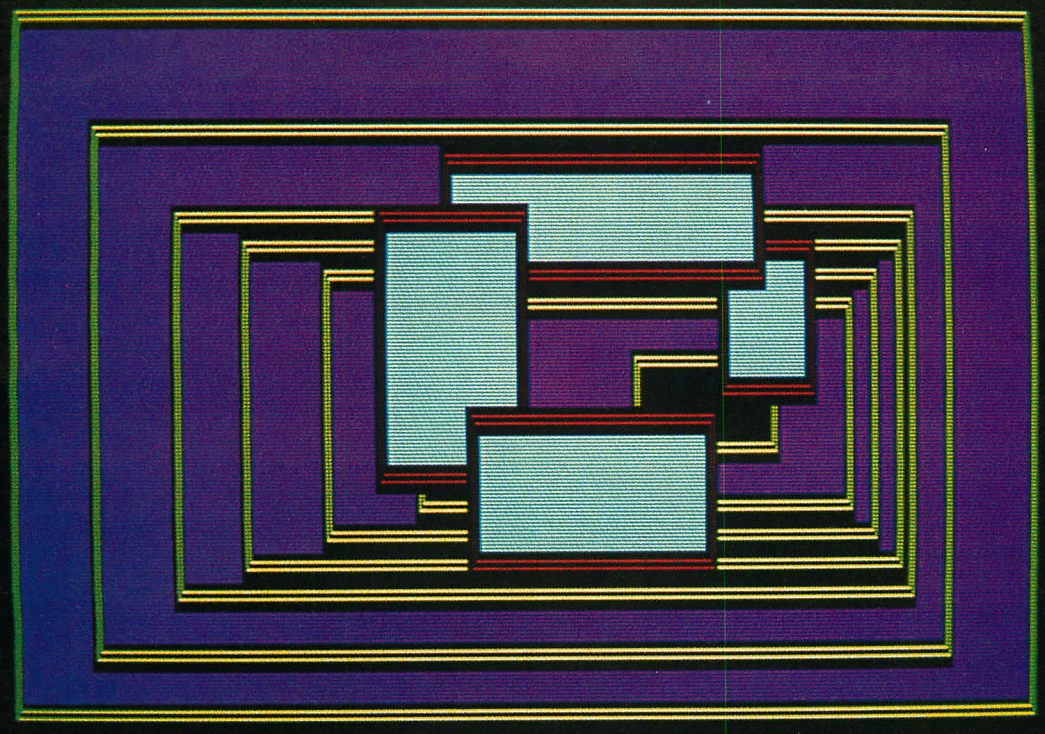
The Soundex Algorithm will not solve all of the problems involved in the retrieval of similar keys or words. Particular situations may demand a more complex form of pattern matching. The interesting point about Soundex, however, is that it was an attempt to achieve a common code for words or phrases that sound alike rather than those that might have syntactical similarities. It is not useful for strings that contain numbers or special characters, and it will not work all of the time.

On the other hand, for alphabetic character strings, it does have a high degree of reliability, making it useful in a variety of retrieval applications. Any data retrieval system in which the keys are proper names, or other alphabetic characters, might benefit from the application of the Soundex Algorithm.

REFERENCE

Knuth, D. E. *The Art of Computer Programming, Volume 3, Sorting and Searching.* Reading, MA: Addison-Wesley Publishing Company Inc., 1973.

Thomas W. Madron, Ph.D., is the manager of computer services at North Texas State University and provides consulting services in many areas, including office automation and management and behavioral science.



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LISTING 1: SOUNDEX.BAS

```
100 ' DEMONSTRATION OF THE SOUNDEX ALGORITHM
105 '
110 ' By Thomas Wm. Madron (1984)
115 '
120 ' Purpose:
125 '
130 '           To demonstrate the calculation of a SOUNDEX code
135 '           from an arbitrary alphameric string.
140 '
145 ' Global Declarations
150 '
155 '   Strings:
160 '
165             NM$="":         ' String to be encoded
170             B$="":          ' Result string from SOUNDEX
175 '
180 '   Integers:
185 '
190             DEFINT A-Z:     ' Define all variables as Integers
195             LL=80:          ' Video Line Length
200             GHL=205:        ' Horizontal Line Graphic
205 '
210 '   Functions:
215 '
220             DEF FNCE$(A$,N)=STRING$(FIX((N-LEN(A$))/2)," ")+A$
225             DEF FNUL$(A$)=CHR$(ASC(A$)+32*(95<ASC(A$)))
230             DEF FNSX$(C$, ALPHA$, NUM$)=
                    MID$(NUM$,INSTR(ALPHA$,C$),1)
235 '
240 '   Subroutines:
245 '
250 '           1000:           Header for Video Display
255 '           2000:           Soundex Subroutine
260 '           3000:           Wait for operator input
265 '
270 ' Begin Main Program:
275 '
280 '   Begin Segment:  Housekeeping
285 '
290             KEY OFF:        ' Turn off function key display
295             GOSUB 1000:     ' Print Video Header
300 '
305 '   End Segment.
310 '
315 '   Begin Segment:  Get sample string
320 '
325         LINE INPUT "Enter Input String or <RETURN> to End: ";NM$
330         IF NM$="" THEN 415
335 '
340 '   End Segment.
345 '
350 '   Begin Segment:  Convert and Print input string
355 '
360             GOSUB 2000:     ' Call Soundex, convert input string
365 '
370             PRINT "Soundex Code is: "; B$
375             GOSUB 3000:     ' Wait for operator input
380 '
385             GOTO 295:       ' Repeat for another trial
390 '
395 '   End Segment.
400 '
405 '   Begin Segment:  End the run
410 '
415             CLS
420             END
425 '
430 '   End Segment.
435 '
440 ' End Main Program.
445 '
1000 ' SUBROUTINE - Header (LL)
1010 '
1020 ' Purpose:
1030 '
1040 '          To print a header at the top of the video display.
1050 '
1060 ' Declarations:
1070 '
1080 ' Integers:
1090 '
1100 '          LL:             Video Line Length
1110 '
```

```
1120 ' Functions:
1130 '
1140 '          FNCE$(A$,N):    String centering function.
1150 '
1160 ' Begin Subroutine:
1170 '
1180           CLS
1190           PRINT FNCE$("Demonstration of SOUNDEX Algorithm",LL)
1200           PRINT STRING$(80,205)
1210 '
1220           RETURN
1230 '
1240 ' End Subroutine.
1250 '
2000 ' SUBROUTINE - SOUNDEX ALGORITHM (NM$, B$)
2010 '
2020 ' Purpose:
2030 '
2040 '          To calculate a Soundex code from an arbitrary
2050 '          alphabetic string.
2060 '
2070 ' Source:
2080 '
2090 '       Knuth, SEARCHING AND SORTING, pp. 391-92, as obtained
2100 '       from Margaret K. Odell and Robert C. Russell,
2110 '       U. S. Patents 1261167 (1918), 1435663 (1922).
2120 '
2130 ' Declarations:
2140 '
2150 '  Strings:
2160 '
2170 '          NM$:            Input String
2180 '          B$:             Output String (Soundex Code)
2190           ALPHA$="ABCDEFGHIJKLMNOPQRSTUVWXYZ" ' Alpha table
2200           NUM$="01230120022455012623010202"   ' Number table
2210 '          C$:             Temporary local variable
2220 '
2230 '  Integers:
2240 '
2250 '          III:            Temporary Index Variable
2260 '
2270 '  Functions:
2280 '
```

```
2290 '          FNSX$(C$,ALPHA$,NUM$):  ' Conversion Table Function
2300 '
2310 ' Begin Subroutine:
2320 '
2330 '  Begin Segment:  Initialize B$ and NM$
2340 '
2350           B$=FNUL$(LEFT$(NM$,1))
2360           NM$=MID$(NM$,2)
2370 '
2380 '  End Segment.
2390 '
2400 '  Begin Segment:  Search and Convert Input String (NM$)
2410 '
2420           FOR III=1 TO LEN(NM$)
2430 '
2440                   C$=FNUL$(MID$(NM$,III,1))
2450 '
2460 '                 Test for Upper Case Alphabetic Characters:
2470 '
2480                   IF ASC(C$)<65 OR ASC(C$)>90 THEN 2590
2490 '
2500 '                 Test for Double Letters:
2510 '
2520                   IF III>1 THEN IF C$=FNUL$(MID$(NM$,III-1,1))
                           THEN 2590
2530 '
2540 '                 Accumulate Ouput String B$:
2550 '
2560                   C$=FNSX$(C$, ALPHA$, NUM$)
2570                   IF C$<>"0" THEN B$=B$+C$
2580 '
2590           NEXT III
2600 '
2610 '  End Segment.
2620 '
2630 '  Begin Segment:  Complete the Output String B$
2640 '
2650           IF LEN(B$)<4 THEN B$=B$+STRING$(4-LEN(B$),"0")
2660           IF LEN(B$)>4 THEN B$=LEFT$(B$,4)
2670 '
2680 '  End Segment.
2690 '
2700           RETURN
```

```
2710 '
2720 ' End Subroutine.
2730 '
3000 ' SUBROUTINE - Wait (LL)
3010 '
3020 ' Purpose:
3030 '
3040 '          To hold the screen until a key is pressed.
3050 '
3060 ' Declarations:
3070 '
3080 '  Strings:
3090 '
3100            Y$="":          ' Temporary Variable
3110 '
3120 '  Integers:
3130 '
3140 '          LL:             ' Video Line Length
3150            LASTLINE=25:    ' Bottom line of Video Display is 25
3160                            ' IF ONLY 24 LINES, CHANGE TO 24!
3170 '
3180 ' Begin Subroutine:
3190 '
3200 '  Begin Segment:  Locate operator notice at last line of
3210 '                  video display.
3220 '
3230            LOCATE LASTLINE,1 ' Locate cursor at bottom line
3240            PRINT FNCE$("Press ANY Key to Continue",LL);
3250 '
3260 '  End Segment.
3270 '
3280 '  Begin Segment:  Loop until key is pressed
3290 '
3300            Y$=INKEY$
3310            IF Y$="" THEN 3300
3320 '
3330 '  End Segment.
3340 '
3350            RETURN
3360 '
3370 ' End Subroutine.
3380 '
```

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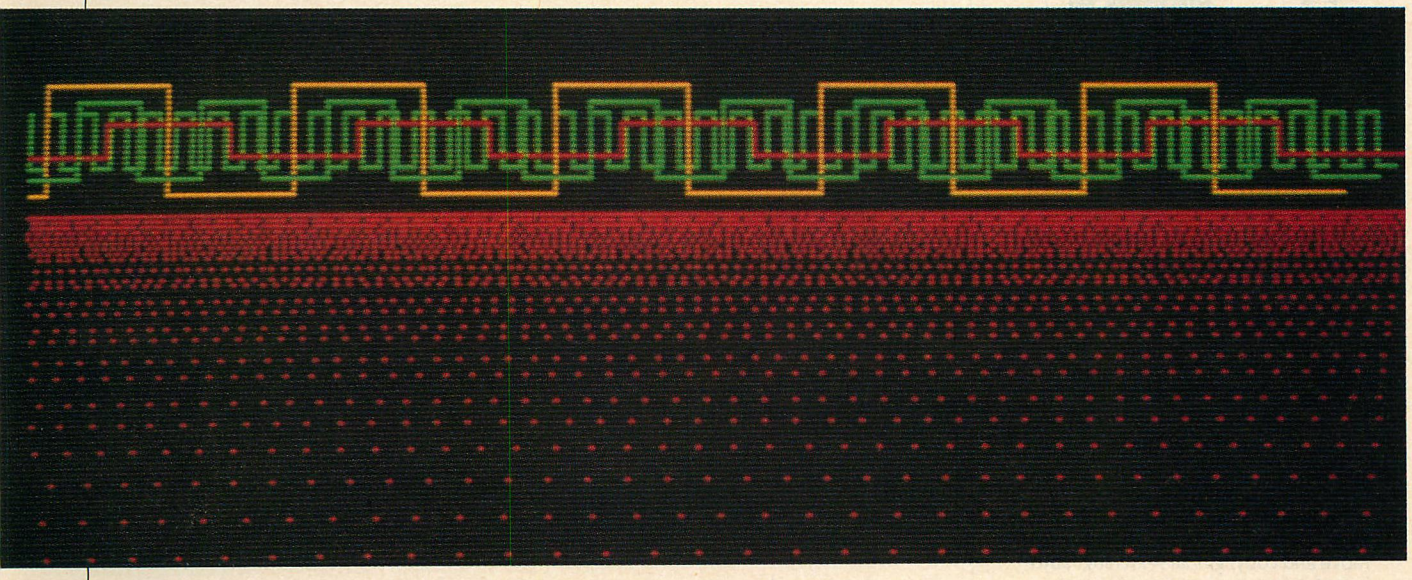
Recursive Curves

A method for drawing fractal curves using IBM's Graphics Definition Language

EUI IN LEE



The Hilbert curve and the Sierpinski curve are two special cases of the general class of fractal curves, which are good challenges to recursive programming. Languages such as Pascal, C, and Logo can handle easily such recursive procedures, but BASIC, in general, cannot do so gracefully. Fortunately, BASICA (Advanced BASIC) for the PC and Cartridge BASIC for PC*jr* can plot these recursive curves using string arrays and a DRAW statement with the Graphics Definition Language (GDL).

In GDL, the primitive movements are defined as single letter commands. The syntax for the DRAW statement is:

DRAW ***string***

where *string* is a string expression consisting of drawing commands in GDL. When the DRAW statement is executed by BASIC, the language commands contained in the string expression are interpreted as single letter commands. The graphics cursor follows each movement command and draws the picture. For example, DRAW "R20 U10 E30" will plot exactly 20 points to the right, then 10 points up and then 30 points in the northeast direction (as shown in figure 1). The colors can be set with the letter C, the scale can be set with S, and the closed region can be painted with P. Figure 2 shows the local movements and command notation in GDL.

The single letter command X will execute a substring and therefore can be used for recursive programming. The syntax is the letter X, followed by the name of an external string variable containing GDL commands, followed by a semicolon. It is also possible to have indexed string variables, as long as the index is not an expression.

The construction of the first three levels (or orders) of the Hilbert curve is shown in figure 3; the program is given in listing 1. At its upper limit, the Hilbert curve completely fills the space and the total length of the curve is infi-

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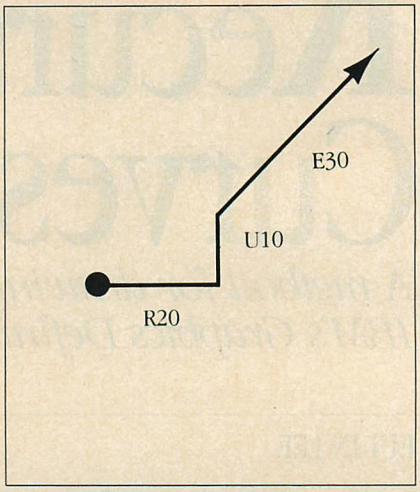
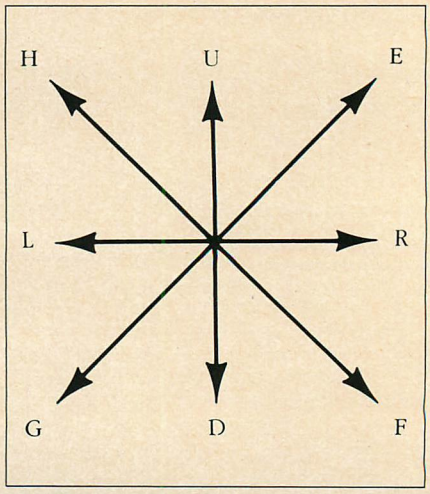
FIGURE 1: *Sample Command*



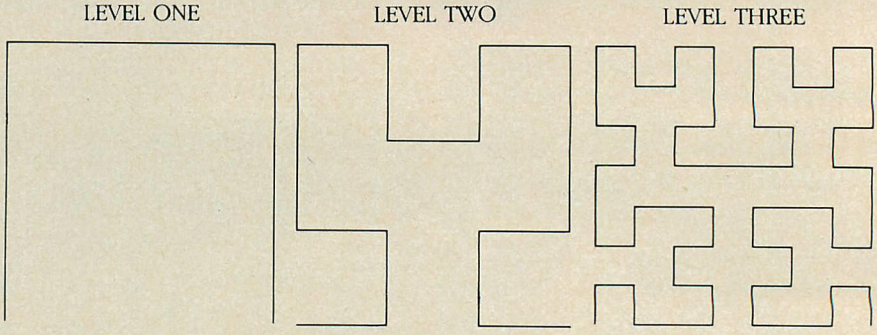
This illustrates the movement commands in DRAW "R20 U10 E30".

FIGURE 2: *GDL Local Moves*



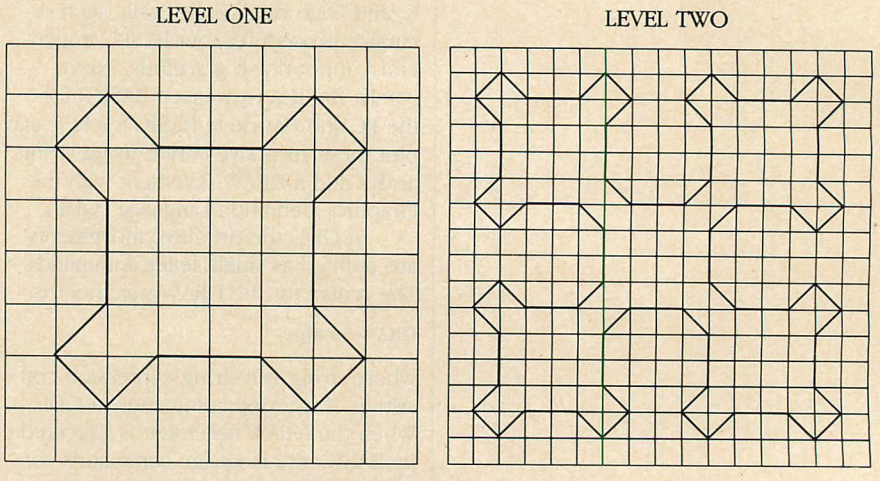
These movement commands begin from the last point referenced.

FIGURE 3: *Hilbert Curves*



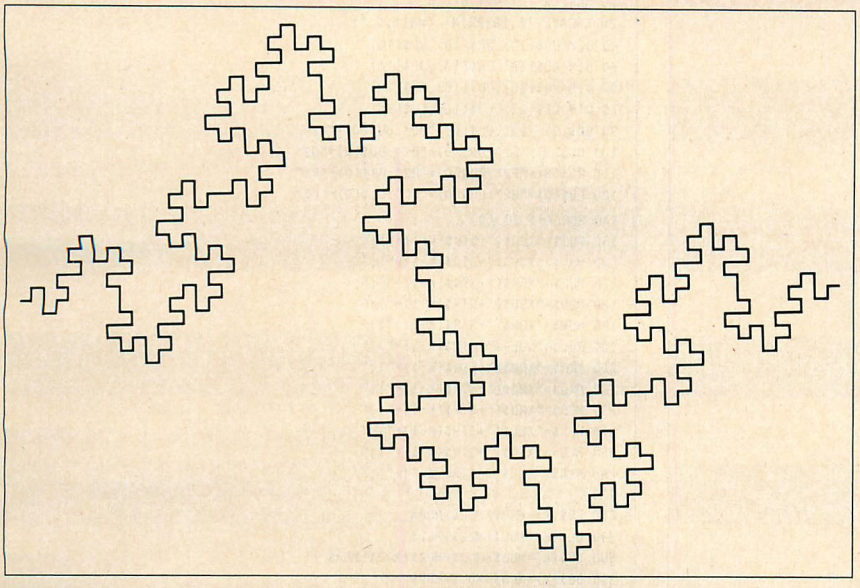
These diagrams show the construction of the first three levels (or orders) of the Hilbert curve. The program to produce these curves is given in listing 1 (HILBERT.BAS).

FIGURE 4: *Sierpinski Curves*



Illustrated here is the construction of the first two levels of the Sierpinski curve. In theory, any level can be plotted, but level five is beyond the screen resolution limit.

FIGURE 5: *A Quadratic Koch Curve*



This sausage-like figure is a quadratic Koch curve of the fractal dimension 1.5. (level three); this gives an indication of the variety possible in generating fractal curves.

nite. This program executes in the following manner. Line 10 selects the medium resolution graphics mode (320 by 200). Lines 40 and 50 reserve the string arrays needed for the curve plotting up to the level ten. Lines 70 through 100 define the primitive motions (level one, so to speak) for drawing the Hilbert curve.

Lines 120 through 300 are the main loop used for generating levels two through ten of the Hilbert curves. The indices are considered as the levels of the curve. Lines 130 through 200 package the strings using X commands, and lines 220 through 290 make up the curve patterns of the current level by calling the curve patterns from the previous level represented by the X commands and the indexed string arrays.

The drawing routine itself is coded in lines 320 through 410. Line 360 is necessary to position the starting point at $x=90$ and $y=150$ and to set the appropriate scale. The actual DRAW statement appears in line 370.

Because only the string arrays are manipulated, the execution time is short. For example, it took only 19 seconds to plot the sixth order Hilbert curve on a PC*jr*. This curve is already beyond the screen resolution; a separate plotter is recommended for Hilbert curves of level six and higher.

The same program can plot the Sierpinski curve and other fractal curves with only a few minor modifications as described below.

The construction of the first two levels of the Sierpinski curve is shown in figure 4 (see listing 2 for the program). Theoretically, Sierpinski curves of any level can be plotted. However, the Sierpinski curve of level five is beyond the screen resolution limit and is therefore not drawn. At its upper limit, the area of the closed region by the Sierpinski curve is five-twelfths and the length of the curve is infinite.

The primitive motions are defined in lines 90 through 120. Level change routines are provided in lines 280 through 390, and again only one DRAW statement is used (in line 470). Line 460 positions the starting point and sets the scale. Line 480 paints the inside of the closed Sierpinski curve. If line 480 is deleted, only the curve will be drawn. Since the aspect ratio of the medium resolution graphics mode on the PC and PC*jr* is not exactly one (it is five-sixths), the resulting Sierpinski curves do not appear to be square.

The Hilbert and Sierpinski curves are two special cases of fractal curves. (The term *fractal* was first used by the mathematician Bernoit Mandelbrot, in his first book *Fractals: Form, Chance and Dimension* (W. H. Freeman, 1977).) A quadratic Koch curve of the fractal dimension of 1.5 (level three) is shown in figure 5 (program in listing 3) to indicate the variety possible in generating fractal curves.

Eui In Lee has a Ph.D. in mechanical engineering. He works for the MIT Lincoln Laboratory in Lexington, Massachusetts, where he is involved in numerical analysis of various thermal and fluidal dynamics problems.

LISTING 1: HILBERT.BAS

```
10 SCREEN 1,1:KEY OFF:CLS
20 LOCATE 12,15:PRINT "Wait...";
40 DIM UU$(10),UR$(10),DD$(10),DL$(10)
50 DIM RR$(10),RU$(10),LL$(10),LD$(10)
70 UU$(1)="U2":UR$(1)="R2U2L2"
80 DD$(1)="D2":DL$(1)="L2D2R2"
90 RR$(1)="R2":RU$(1)="U2R2D2"
100 LL$(1)="L2":LD$(1)="D2L2U2"
110 '
120 FOR K=2 TO 10
130 MUU$="XUU$("+STR$(K-1)+");"
140 MUR$="XUR$("+str$(k-1)+");"
150 MDD$="XDD$("+STR$(K-1)+");"
160 MDL$="XDL$("+STR$(K-1)+");"
170 MRR$="XRR$("+STR$(K-1)+");"
180 MRU$="XRU$("+STR$(K-1)+");"
190 MLL$="XLL$("+STR$(K-1)+");"
200 MLD$="XLD$("+STR$(K-1)+");"
210 '
220 UU$(K)=MUU$
230 UR$(K)=MRU$+MRR$+MUR$+MUU$+MUR$+MLL$+MLD$
240 DD$(K)=MDD$
250 DL$(K)=MLD$+MLL$+MDL$+MDD$+MDL$+MRR$+MRU$
260 RR$(K)=MRR$
270 RU$(K)=MUR$+MUU$+MRU$+MRR$+MRU$+MDD$+MDL$
280 LL$(K)=MLL$
290 LD$(K)=MDL$+MDD$+MLD$+MLL$+MLD$+MUU$+MUR$
300 NEXT K
310 '
320 FOR K=1 TO 6:SIDE=2^K-1
330 SCAL=252/SIDE:CLS
340 LOCATE 1,1:PRINT "Level";K
350 '
360 DRAW "BM90,150;S=SCAL;"
370 DRAW RU$(K)
380 '
390 LOCATE 22,1
400 INPUT "Press ENTER to continue";A$
410 NEXT K
420 END
```


LISTING 2: SRPNSKI.BAS

```
10 SCREEN 1,1:KEY OFF:CLS
20 LOCATE 12,15:PRINT "Wait...";
40 DIM UU$(10),UR$(10),UL$(10)
50 DIM DD$(10),DR$(10),DL$(10)
60 DIM RR$(10),RD$(10),RU$(10)
70 DIM LL$(10),LD$(10),LU$(10)
90 UR$(0)="E2":UL$(0)="U2":UU$(0)="U2"
100 DL$(0)="G2":DR$(0)="D2":DD$(0)="D2"
110 RD$(0)="F2":RU$(0)="R2":RR$(0)="R2"
120 LU$(0)="H2":LD$(0)="L2":LL$(0)="L2"
140 FOR K=1 TO 10
150 MUU$="XUU$("+STR$(K-1)+");"
160 MUL$="XUL$("+STR$(K-1)+");"
170 MUR$="XUR$("+STR$(K-1)+");"
180 MDD$="XDD$("+STR$(K-1)+");"
190 MDR$="XDR$("+STR$(K-1)+");"
200 MDL$="XDL$("+STR$(K-1)+");"
210 MRR$="XRR$("+STR$(K-1)+");"
220 MRU$="XRU$("+STR$(K-1)+");"
230 MRD$="XRD$("+STR$(K-1)+");"
240 MLL$="XLL$("+STR$(K-1)+");"
250 MLD$="XLD$("+STR$(K-1)+");"
260 MLU$="XLU$("+STR$(K-1)+");"
270 '
280 UU$(K)=MRU$+MUR$+MUU$
290 UL$(K)=MUL$+MLU$+MLL$
300 UR$(K)=MUL$+MLU$+MUR$+MRD$+MRR$
310 DD$(K)=MLD$+MDL$+MDD$
320 DR$(K)=MDR$+MRD$+MRR$
330 DL$(K)=MDR$+MRD$+MDL$+MLU$+MLL$
340 RR$(K)=MDR$+MRD$+MRR$
350 RU$(K)=MRU$+MUR$+MUU$
360 RD$(K)=MRU$+MUR$+MRD$+MDL$+MDD$
370 LL$(K)=MUL$+MLU$+MLL$
380 LD$(K)=MLD$+MDL$+MDD$
390 LU$(K)=MLD$+MDL$+MLU$+MUR$+MUU$
400 NEXT K
410 '
420 FOR K=1 TO 4:SIDE=2^(K+1)
430 SCAL=128/SIDE:CLS
440 LOCATE 1,1:PRINT "Level";K;
450 '
460 DRAW "C3BM160,90;S=SCAL;BL4"
470 DRAW UR$(K)+RD$(K)+DL$(K)+LU$(K)
480 DRAW "BR P3,3"
490 '
500 LOCATE 22,1
510 INPUT "Press ENTER to continue";A$
520 NEXT K
530 END
```

LISTING 3: FRACTAL.BAS

```
10 ' FRACTAL CURVE -- Q.KOCH D=1.5
20 '---------------- SAUSAGE LINK
40 SCREEN 1,1:KEY OFF:CLS
50 LOCATE 12,17:PRINT "Wait...."
70 DIM U$(10),R$(10),L$(10),D$(10)
90 U$(0)="U2":R$(0)="R2":L$(0)="L2"
100 D$(0)="D2"
120 FOR K=1 TO 10
130 MU$="XU$("+STR$(K-1)+");"
140 MR$="XR$("+STR$(K-1)+");"
150 ML$="XL$("+STR$(K-1)+");"
160 MD$="XD$("+STR$(K-1)+");"
170 '
180 U$(K)=MU$+ML$+MU$+MR$+MR$+MU$+ML$+MU$
190 R$(K)=MR$+MU$+MR$+MD$+MD$+MR$+MU$+MR$
200 L$(K)=ML$+MD$+ML$+MU$+MU$+ML$+MD$+ML$
210 D$(K)=MD$+MR$+MD$+ML$+ML$+MD$+MR$+MD$
220 NEXT K
230 FOR K=1 TO 4:CLS
240 SIDE=4^K:SCALE=512/SIDE
250 LOCATE 1,1:PRINT "Level";K
260 '
270 DRAW "BM30,90;S=SCALE;"
280 DRAW R$(K)
290 '
300 LOCATE 22,1
310 INPUT "Continue ";A$
320 NEXT K
330 END
```

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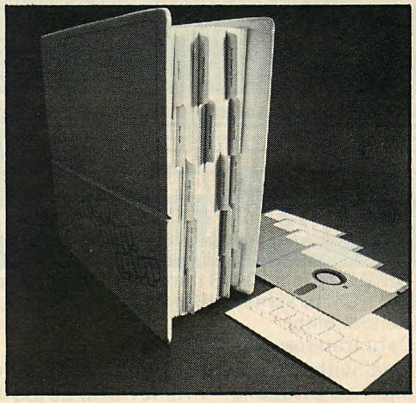

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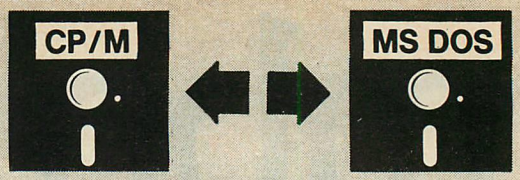

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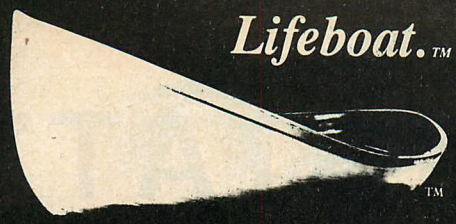

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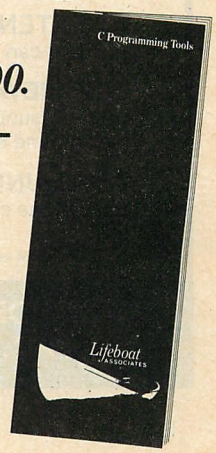

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The Compatibility Risk

Manufacturers of compatibles may have the choice to sue or be sued.

The production of a compatible computer creates an unavoidable dilemma. The compatible must be similar enough functionally to run software written for its "idol." To the extent that hardware is required to achieve this purpose, the compatible manufacturer must respect any applicable patents; to the extent that software is required, it must avoid infringing copyrights. The dilemma is between approaching functional equivalence and avoiding infringement. The problem usually is most acute with respect to what has come to be known as operations software: Apple Computer compelled Franklin Computer to cease using an allegedly infringing DOS; IBM compelled several companies to cease using an allegedly infringing BIOS.

In this column in December 1984 ("Compatibles and Copyrights," p. 210), the question was raised whether a noninfringing compatible could exist. One of the wrong answers was "No." To overgeneralize the copyright law, *copying*, not *similarity of expression*, is forbidden. Theoretically speaking, even identical expression would not be infringement if the identical expression had been independently created.

On the other hand, expression need not be identical to be infringing. The use of substantial portions (even relatively short, though key, portions) of a work may constitute infringement. Furthermore, the creation of a *derivative* work is the sole right of the copyright owner. At one time, it may have been clear what constituted a derivative work—the author of a book had the right to produce a derivative play or movie. The issue becomes more complicated when the subject matter is far removed from common experience (or, more importantly, from experience that a judge or jury is likely to have), as cases in which the work is written in machine code. It would require expensive expert testimony to establish whether one machine language program is the derivative of another.

Still, in theory at least, a company that produces similar software in an effort to achieve compatibility has nothing to fear if it independently creates the necessary code.

Enough theory. The real world does not work like that. If Comparable Computer Corporation produces a machine that is compatible with Idol Business Machine's model, Comparable can expect a letter from Idol's attorney. The letter most likely would not say how flattered Idol was at such superb imitation; instead, it would stress how valuable Idol's copyrights are and how trouble could be avoided if Comparable went into some other line of work.

Comparable's problem is that, by definition, its code must be similar to Idol's, at least in the sense that it must accomplish the same functions and, in many cases, must accomplish them in very narrowly defined ways. Franklin argued (see "Memories are Made of This," *PC Tech Journal* June 1984, p. 34) that an idea and its expression might be so closely related that the idea might be expressed in only one way, that the idea and its expression might thus merge, and that to enforce a copyright in such a situation would be to monopolize the idea (a result that the Copyright Act clearly does not require). The court agreed, but held that Franklin had not demonstrated that to be the case with respect to the Apple programs Franklin had admitted copying.

Comparable Computer Corporation may try to avoid both the idea-expression merger issue and the question of when a work specifically intended to be compatible with another copyrighted work is derivative by concentrating on establishing the independence of its creation. Comparable might create what lawyers refer to as a "Chinese Wall" between two teams of programmers, one of which would familiarize itself with Idol's program, determine the elements of compatibility, and test the code produced by a second team, which would be given the first team's specifications for compatibility, but have no access to Idol's code.

Ideally, communications between the two teams would be in writing and be reviewed by a third team whose job would be to censor any communication of Idol's expression, as opposed to its ideas. The theory behind such an approach is that independent creation is not infringement, even if the result of such creation is an identical work.

The difficulty in the implementaton of the theory is twofold: extreme care must be taken to monitor the flow of information between the two teams to assure that the first team does not, in its specifications or otherwise, disclose critical portions of Idol's code; extreme care must also be taken to select members of the second team who have not had prior access to Idol's code. The latter requirement may be particularly troublesome when the code has been published and widely distributed. Finally, judgment must be exercised when the second team says that it needs more detail from the first team.

Since courts frequently are able to determine the truth, it would be helpful if, in fact, Comparable independently created its code. Unfortunately, that determination will not be made by a court until both sides have come before it and presented their evidence. In other words, Comparable must either sue or be sued. Both options are expensive. Not knowing whether a court will enjoin production of its compatible machine, impound existing machines, prohibit their importation into the United States, award damages, and assess costs makes the introduction of a compatible machine a risky venture. Most companies would prefer not to commit significant resources without doing what they can to reduce that risk.

One approach Comparable might take would be to contact the owner of the copyright on the original machine (who, since the object is compatibility, will be known) to try to arrange a mechanism to compare the two products and determine, in a civilized fashion, whether there is a problem. The goal of the process would be to reach agreement that Comparable has not infringed Idol's copyright or that it has (and, if so, what must be done to eliminate the infringing elements).

This mutual agreement approach presents problems of its own. It requires disclosure of Comparable's intention to enter the market; it requires disclosure of information that Comparable may prefer to keep out of its competitor's hands; and it offers Idol little incentive to agree that the code does not infringe. If Idol refuses to come to such an agreement, Comparable must decide whether to go to market in the face of a more fully informed competitor and whether it is willing to risk a lawsuit that will probably include the allegation that "on said date, Idol informed Comparable that its code infringed Idol's copyright and demanded that Comparable cease and desist from said infringing activities, but nevertheless, with knowledge of the wrongful nature of its actions, Comparable willfully and deliberately proceeded with full knowledge that by doing so it was violating Idol's copyright." That result might make the alternative of simply waiting to be sued look attractive.

Another approach would be to find a neutral forum of some kind for deciding the infringement issue in advance of substantial production and marketing expenditures. Idol, however, would have less incentive to submit voluntarily to such a forum than it would to the mutual agreement approach.

In a recently filed, lawsuit, Nippon Electric Corporation (NEC) is attempting to compel INTEL to resolve a copyright dispute in a neutral forum: a federal district court. Rather than waiting for INTEL to decide whether the code on NEC's V20 and V30 chips infringe INTEL's copyrighted code on its 8086 and 8088 chips, NEC took the legal offensive and sued INTEL, asking the court to issue both a declaratory judgment that the NEC chips do not infringe INTEL's copyrights and also an injunction prohibiting INTEL from suing NEC for infringement. NEC's pleadings indicate that it had tried the mutual agreement approach and that INTEL said it believed the V20 and V30 chips would violate its copyrights.

Whether the court will hear the merits of the case remains to be seen. It could dismiss the case on jurisdictional grounds. The U.S. Constitution grants U.S. courts the power to decide "cases" and "controversies." In a 1928 Supreme Court case (*Willing* v. *Chicago Auditorium Association*), Justice Brandeis wrote that the fact that a party's "desires are thwarted by its own doubts, or by the fears of others, does not confer . . . a cause of action." A subsequently enacted law, the Federal Declaratory Judgment Act, gave federal courts the power to "declare" the rights of parties "in a case of actual controversy." Declaratory judgment actions are comparatively uncommon, and the distinction between a "case" or "controversy" and a nonjusticiable "doubt" is not clearly defined.

In the NEC case, if the court finds that no actual controversy yet exists, NEC will have to choose between abandoning its investment or proceeding with production and importation of the chips and awaiting INTEL's move. If NEC succeeds in maintaining the suit (whether it wins or loses on the merits), it will have established a potentially powerful tool for makers of compati-

bles. If the suit is dismissed for want of a "case" or "controversy," compatible manufacturers will have to run the risk of being enjoined once production has started, or of trying to reach a mutual agreement with a competitor that has little incentive to cooperate, or of finding another neutral forum.

NEW PC TAX RULES

Considerable publicity has been generated by the Deficit Reduction Act of 1984, which has reduced the tax benefits of buying a personal computer. While the act does restrict the benefits in some situations, in many others tax savings still may be possible.

The act does not apply to computers purchased before June 18, 1984 (or that had a sales contract placed on them before June 18 and were put into service before January 1, 1985). Owners of these computers are still allowed depreciation under the Accelerated Cost Recovery System and a tax credit if the machine is used primarily for business purposes. Or, up to $5,000 could be deducted immediately in lieu of depreciation and tax credit.

Under the new rules, these tax benefits are available only if certain additional tests are met: (1) more than half of the computer's use must be for business; (2) business use must be established by *contemporaneous* records; (3) if the business use relates to the user's employment, the use must be both for the convenience of the employer and a condition of employment.

If you have more than one employer, the test applies to the one for which the computer is used. If you have a regular job at which a computer is available to you, proving the condition of employment rule will be difficult. However, if you use the computer exclusively for another money-making business purpose (consulting, for example), you are home free, taxwise.

Other points to remember: a qualifying home office may exempt you from the new rules. The Deficit Reduction Act has an exemption for computers used exclusively at a regular place of business. Also note that the contemporaneous requirement can be met with a "log" program or a notebook next to the computer.

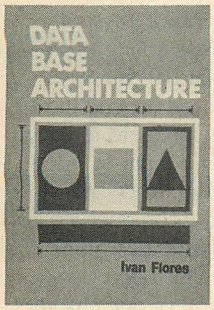
If you cannot meet the new tests, you can at least take pride in helping to reduce the country's deficit.

Max Stul Oppenheimer, PC, is a partner in the law firm of Venable, Baetjer & Howard, located in Baltimore, Maryland.

Learning DBMS

This textbook may help microcomputer applications developers expand their knowledge of database management beyond file-management techniques.

Data Base Architecture
Ivan Flores (Van Nostrand and Reinholt, New York, 1981) 396 pages, $28.50



A clear understanding of database management is a vital and essential prerequisite to a full exploitation of microcomputers. This understanding forms the foundation for using database management tools effectively in constructing large-scale, professional-quality applications systems that are capable of handling huge volumes of intricately interrelated data.

The remarkable applications development possibilities that are available today via microcomputer database management systems (DBMSs) are still largely unrecognized, even among the more technically oriented microcomputer users and among experts in mainframe DBMS usage. This is a result of the widespread dilution of the term *database management* in the micro world, relative to its standard meaning in the mainframe world. Micro-based file management has come to mean database management; micro software that reads/writes/merges records for one or more files is routinely called a *DBMS* or a *relational DBMS*, even though it does not adhere to the relational data model's access languages.

This dilution of terminology has led to the present situation, in which the multitude of micro file managers largely obscure those few highly sophisticated micro DBMSs that do exist. Upon scanning the micro DBMS offerings, a mainframe DBMS expert is all too likely to conclude erroneously that extensive applications systems for microcomputers cannot be developed using techniques from sophisticated mainframe DBMSs. On the other hand, micro applications systems developers who unknowingly restrict themselves to file management will remain oblivious to what can be achieved with the more advanced micro DBMS tools.

The problem of educating the micro world about advanced, classic database management has not been solved by recent paperback books dealing with "database" management for micros. With a couple of exceptions, these deal almost exclusively with managing records within files. To the extent that they endeavor to present the major data models, their descriptions are at best superficial and are all too often inaccurate. Serious applications developers interested in going beyond file management must look elsewhere.

Ivan Flores' *Data Base Architecture* is one possible source for information about database management. Although this book, like those by Bradley (*File & Data Base Techniques*. Holt, Rinehart and Wilson, 1982), Cardenas (*Data Base Management Systems*. Allyn and Bacon, 1984) and Kroenke (*Database Processing*. SRA, 1983) is not oriented toward microcomputers, it is useful as an introduction to classic database management. The fundamental DBMS concepts and principles are equally valid for different host machine sizes.

Flores' book is intended as an elementary text for the technically oriented reader. Persons unaccustomed to mathematical formalisms may find some portions of the book difficult to appreciate. However, the treatment of material is considerably more accessible than the presentation style used in some other DBMS texts for example, the Wiederhold book (*Database Design*. McGraw-Hill Publishing Company, 1983).

Chapter 1 contrasts file-management approaches to applications development with the database-management approach. The problems inherent in using a single large file or multiple files are explained, and the advantages of a database that avoids data fragmentation are presented. A broad overview of the purpose, constitution, and activities of a DBMS is also presented in chapter 1. A more detailed treatment of these activities is presented in chapter 4.

The second chapter is concerned with identifying the kinds of binary relationships that can exist between real applications-world entities. The book uses the term *relation* instead of *relationship* to refer to a relationship between two entities. Although this usage is consistent throughout the book, the reader must be careful not to confuse such usage with the conventional relational data model's usage of *relation* to refer to a table of data. Like most database textbooks, this book has little to say about unary and n-ary (forked) relationships, even though applications developers often must deal with them.

The architectural aspects (that is, logical-structuring facilities) of three conventional data models—relational, network, and hierarchical—are introduced in chapter 3. Here, *network* is used in the sense of CODASYL-network. The shallow-network data model—architecturally a restricted version of the CODASYL—is not discussed. The author clearly explains how the three data models differ in their facilities for representing real-world relationships. But the descriptions of these facilities unnecessarily mix the logical and physical realms. For instance, the logical construct of a CODASYL set is described in terms of a chaining approach to set implementation. Although most implementations of the CODASYL rely on chaining, this is relevant neither to the model's logical structure nor to the use of its access language. The discussion of physical structuring would have been better left to a separate chapter.

Unfortunately, the book does not discuss the architectural aspects of a

data model that is highly relevant for micro applications systems developers: the postrelational data model (sometimes called the extended-network model). This model may have been omitted because initial implementations of it were relatively new at the time the book was published. Database textbooks whose authors have a mainframe orientation often omit this model.

Chapters 5 and 6 cover the relational model in more detail. Formal relational terminology is introduced, the PROJECT and JOIN operators that form the basis of the low-level relational access language (that is, relational algebra) are explained, and the mechanics of normalization are presented. The first through fourth normal forms are explained and illustrated with examples.

Chapters 7 and 8 provide examples of small schematic CODASYL-network structures, although these are not depicted in terms of traditional Bachman diagrams. The sample occurrence structures for these schemas are portrayed as being implemented via chaining, which detracts somewhat from the simplicity of the data model's logical view. The schematic examples illustrate the various architectural possibilities that exist with this data model. They include examples of how artificial record types and additional sets can be used to indirectly represent the many-to-many and recursive relationships that exist in the real world. One point that may confuse some readers is the author's mention of "many-to-many sets." These are, of course, not supported by the CODASYL-network; they are supported only in the postrelational data model. What the author shows is how to make up for CODASYL's lack of these sets.

In chapters 9 and 10, sample hierarchical schemas are presented, intermixed with a discussion of physical structuring (closely resembling IBM's DL/1). Included is a fairly extensive discussion on how to get around the inability of a pure hierarchy to directly represent transitive and many-to-many relationships. The redundancy and pointer-based-pairing techniques for circumventing this problem are competently described and illustrated.

With the exception of one chapter that describes the role of secondary key indexing, the book's remaining chapters deal with the various languages an applications developer would encounter in using a DBMS. As suggested by the book's title, the language aspects of the selected data models are covered in less depth than the architectural aspects. However, the treatment is sufficient to give the reader a good taste of what is involved in using a data-description language, a data-manipulation language, and a query language. The examples and discussion of these languages has a predominately hierarchical flavor. Surprisingly, no discussion has been included of the structured query language, which is the standard query language for the relational data model; all relational language examples are confined to the relational model's low-level algebraic language, which involves the relatively cumbersome PROJECT and JOIN operators.

This book can serve as a useful (though not ideal) starting point for technically oriented microcomputer users who want to begin exploring the world of database management that exists beyond rudimentary file management. The book does not cover the postrelational model, an understanding of which is mandatory for comprehension of the micro DBMS field.

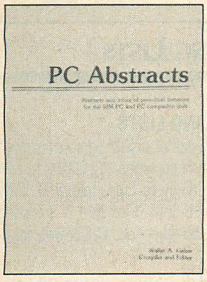
This textbook (like others of its genre) is concerned only with the concept of database management; readers should not expect it to teach them how to develop elaborate applications systems with a DBMS tool. The emphasis is on what a DBMS is (particularly in an architectural sense), rather than on what can be done with a DBMS.

Finally, the reader should be aware that there is much more to a full-scale DBMS than its data model. These additional issues include data security mechanisms, performance-tuning controls, integrity/recovery facilities, multiuser processing methods, and applications development aids. None of these topics is discussed in this book.

—CLYDE HOLSAPPLE

PC Abstracts, 1983 edition
Walter A. Gaber (Artrice Press, 1983) 88 pages; paper, $15.95

PC Abstracts, 1984 edition
Walter A. Gaber (Garland Publishing, 1984) 541 pages; paper, $60.00



There are few fields in which information gets old as quickly as it does in the field of microcomputing. For a writer or consultant who *must* stay on top of the state of the art (his living depends on it), this means keeping (large) stacks of magazines *and* having a means of zeroing in on a particular subject quickly.

Although most academic fields are covered by one or more volumes of abstracts, the field of IBM Personal Computing has but one: *PC Abstracts*. Walter A. Gaber's own firm, Artrice Press, published a single volume for all of 1983, which abstracted IBM PC-specific material from the following periodicals: *BYTE, Creative Computing, PC Data, PC Magazine, PC Tech Journal, PC World, PC Age, Programmer's Journal, Reference/Business Computing*, and *Softalk IBM*. Beginning in 1984, Garland Publishing assumed production and marketing of *PC Abstracts* with Gaber still handling the editorial end. The 1984 edition, now available, abstracts PC-specific material from *BYTE, Creative Computing, PC Age, PC Magazine, PC Tech Journal, PC World, PCjr World* (actually included in *PC World*), *Programmer's Journal, Business Computing*, and *Softalk IBM*.

The 1983 edition has 1,503 article summaries; the January-June 1984 edition has 1,351, the last one published by Gaber. Each summary is numbered, and the author and subject indexes cite article numbers rather than page numbers. Summaries are divided into five major categories: Hardware, Software, Applications, Market/News, and Commentary. Within each category are subcategories, such as (under Hardware) Monitors, Modems, Printers and Plotters, Keyboards, and Mice.

Each summary is from 15 to 100 words long; most are 30 to 40 words. Gaber has done a creditable job in condensing key topics to a handful of words, and the book has been typeset in a small, but readable, typeface. The exploding coverage of the IBM PC family in the computer press can be gauged by the fact that only 88 pages covered all of 1983, but for 1984, equivalent coverage jumped to 541 pages!

—JEFF DUNTEMANN

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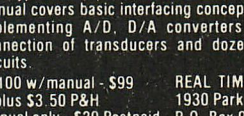

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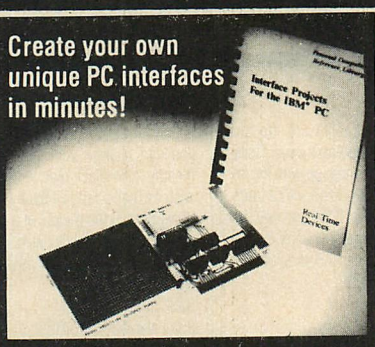

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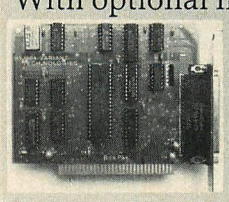

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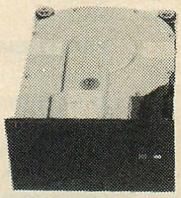

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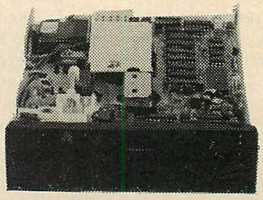

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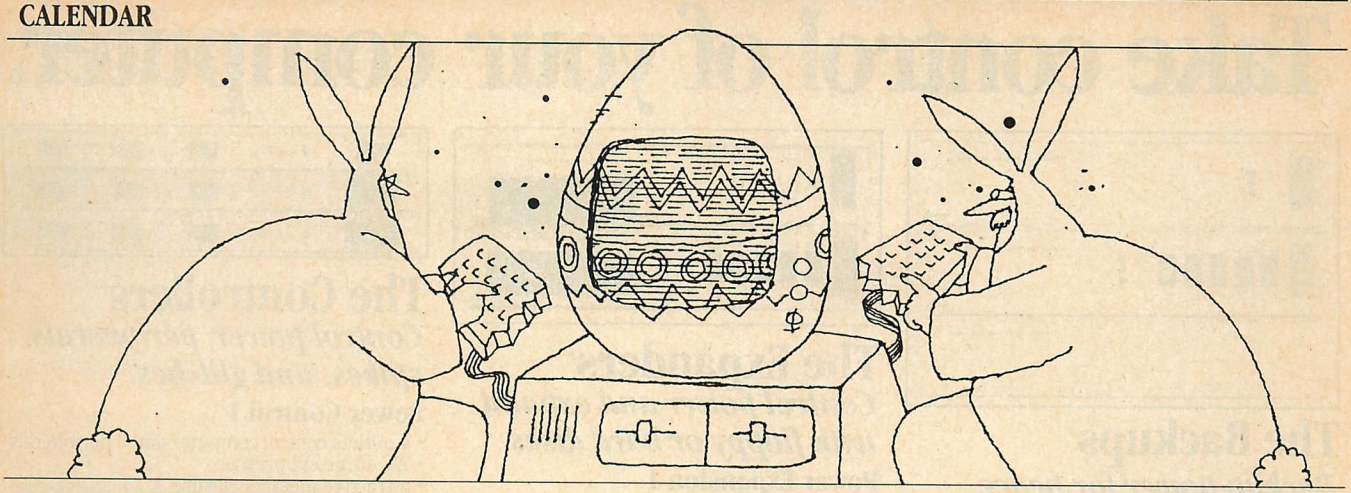

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New Orleans, LA
Contact: Northeast Exposition, 822 Boylston Street, Chestnut Hill, MA 02167; 617/739-2000

April 14-18
Computer Graphics 85—The NCGA's Sixth Annual Conference and Exposition (ACM)
Dallas, TX
Sponsor: National Computer Graphics Association
Contact: NCGA, 8401 Arlington Blvd., Suite 601, Fairfax, VA 22031; 703/698-9600

April 14-18
CHI 85: Conference on Human Factors in Computing Systems
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Contact: D. Austin Henderson, Jr., Xerox PARC, 3333 Coyote Hill Road, Palo Alto, CA 94304

April 15-17
Conference on Software Tools
New York, NY
Sponsor: Polytechnic Institute of New York in cooperation with ACM and IEEE TCSE
Contact: Martin L. Shooman, Polytechnic Institute of New York, 333 Jay Street, New York, NY 11201; 212/643-5174

April 20-21
10th Annual Trenton Computer Festival
Trenton, NJ
Sponsors: Amateur Computer Group of New Jersey, et al
Contact: Department of Electronics Engineering Technology, Trenton State College, Hillwood Lakes CN 550, Trenton, NJ 08625; 609/771-2487

April 23-25
Federal DP Expo and Conference
Washington, DC
Contact: Amy Marks, The Interface Group, 617/448-6600

April 23-26
UNIX SYSTEMS EXPO/85—Spring
San Francisco, CA
Contact: Sally O'Neill, Computer Faire, Inc., 181 Wells Avenue, Suite 201, Newton, MA 02159; 800/826-2680 or 617/965-8350

April 23-26
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Contact: Robert P. Bostrom, Business 574, Indiana University, Bloomington, IN 47405; 812/335-8449

May 6-8
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May 6-9
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Atlanta, GA
Contact: Amy Marks, The Interface Group; 617/449-6600

May 12-16
APL 85
Seattle, WA
Sponsor: ACM SIGAPL and Puget Sound Chapter of ACM
Contact: Robert Gailer, 12122 N.E. 150th Street, Kirkland, WA 98033; 206/575-7476

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Contact: J. A. N. Lee, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; 703/961-6931

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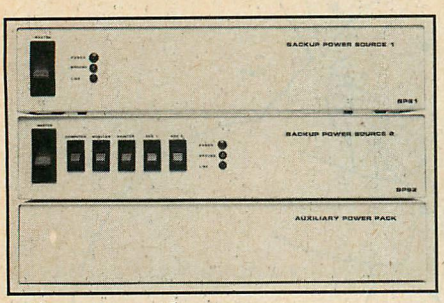

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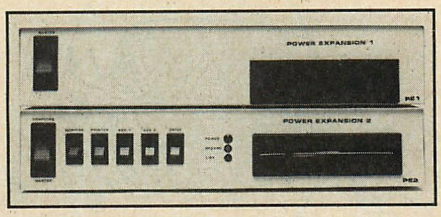

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All the features of Power Expansion 1 plus:

- 6 outlets controlled by front switches
- 10 amp master switch circuit breaker
- LED ground and line indicators
- 3 stage noise filter
- cross suppression between all 6 outlets
- optional internal power supply
- optional floppy and hard disk drives

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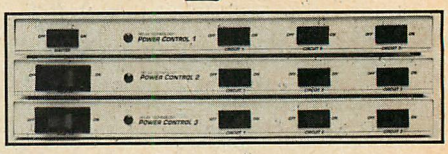

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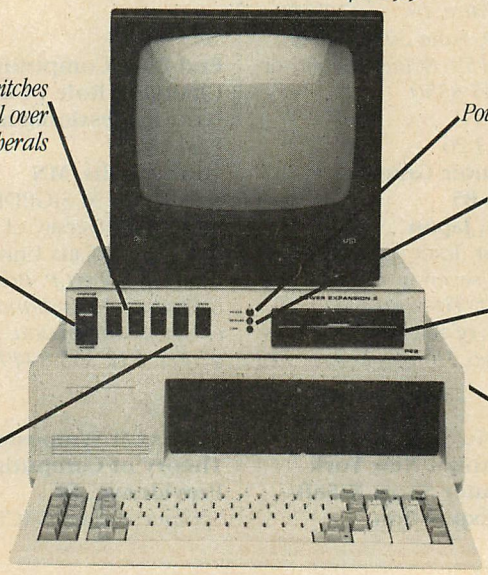

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Professional Pascal™

Smaller & Faster code Plus 22 reasons for not using Microsoft® Pascal

The List:

Compile Time
Symbol table space limited only by available memory
Cross referencer
ANSI–standard checking
Option to search a list of directions to find any input file
Source interleaved with Object in Object listing
Full Intel OMF Line/Symbol/Type records for debugger
Run Time
Code quality
Five models of memory on the 8086: small, medium, compact, big and large
Code produced suitable for ROM
Expressions
Long/short integer mixes
Set constant expressions
Set elements in the range $-2^{31}..2^{31}-1$ or 0..256
Type casts
// = Concat for concatenation of all strings
Statements
Iterators (for data abstraction from CLU)
Assignment to string variables of differing lengths
Declarations
Otherwise (or else) in record declarations
Intrinsics
ReadIn(X:M)
Inc, Dec, Incl, Decl, from Modula–2
Data Types
Comparison (for equality) of record or array types
The value -32768 allowed as an integer
Maximum size of a data structure on the 8086

Information on Microsoft Pascal obtained from the 1984 release 3.2. printing of the MS manual.

Microsoft has a problem. The 22 features listed above are missing from MS Pascal.

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